THE SCOTTISH GEOGRAPHICAL MAGAZINE

Volume 76, No. 1 April, 1960

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THE SCOTTISH
GEOGRAPHICAL
MAGAZINE

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THE SINO-INDIAN FRONTIER DISPUTE

A GEOGRAPHICAL REVIEW

WILLIAM KIRK

There is no special interest in the northern sections of the Indian frontier from the Kashmir hinterland to where it passes north of the protected States of Nepal, Sikkim and Bhutan to the Brahmaputra, beyond one dominant feature: it is the finest combination of boundary and barrier that exists in the world.... never was there such a God-given boundary set to such a vast, impressive and stupendous frontier.

Holdich. *Political Frontiers & Boundary Making*, 1916.

AMONG the many problems inherited in 1947 by the successor states to the British Raj in Southern Asia one of the most important and difficult was the assumption of responsibility for the maintenance of the landward frontier defensive screen erected by British military and political action during the preceding hundred years. States which had come into being on a wave of communal, nationalist, and anti-imperialist emotions, were now required to establish relations and honour treaty obligations with a series of northern frontier kingdoms that had taken shape under the mantle of British imperialism. To Pakistan fell the task of guarding the fateful land-gates leading from Soviet Central Asia around the western flanks of the Himalayan barrier, and of establishing contact with the former 'buffer' state of Afghanistan and adjacent mountain tribes. Burma, devastated by war and social disintegration, and suffering from grave disabilities as a result of lack of governmental control in the interior of the country, assumed responsibility for the tenuous but important thoroughfares of the eastern flank leading from China to the Indian Ocean. India, on the other hand, was committed to the defence of an extensive frontier zone stretching along the glacis of the main Himalayan system and including such kingdoms as Nepal, Sikkim, Bhutan, Kashmir and the tribal frontier tracts of Assam. To the north lay the highland wastes and backward kingdom of Tibet, owing allegiance to China but for many years virtually independent of her ancient suzerain, with as many links southward as eastward. Such a terrain and people appeared to constitute little threat to the military

security of India and it is hardly surprising that India concentrated her energies elsewhere, on other problems. There is thus a certain grim irony in the fact that this frontier zone, the traditional natural sentry of India, has in little over a decade become one of the trouble spots of Asia. It affords a notable example of the manner in which in the modern world lacunae of power represented by indeterminate frontier zones attract the ingression of major powers, and of how the mutual relations of the latter can change when spheres of influence become national territories and frontier zones narrow to common boundary lines.

The process whereby a broad frontier zone has become a disputed boundary line may be briefly summarised. British frontier policy, as formulated in the latter part of the nineteenth century, was based on the principle of never forcing the communities of the peripheral buffer-zone with Central Asia into British-Indian sovereignty if this could be avoided. Their cultural freedom was respected and political autonomy protected on condition that they excluded other foreign forces. Relations with these so-called 'buffer states' were characterised by that vague but purposive flexibility inherent in British statesmanship on the frontiers of empire. Personal contacts were preferred to protocol, and the nuisance of tribal warfare to the dangers of facing a Great Power along a common frontier [1]. In the successful pursuit of that policy in Northern India they were assisted by the nature of the terrain, the poverty of communications, the isolation of varied communities, and the continued weakness of the Chinese Empire in Central Asia. Since World War II, however, both India and China have sought to increase the measure of direct control over their respective spheres of influence in the frontier zone [2].

The new Government of India has attempted to regularise the somewhat loose political affiliations inherited from the British period by abrogating former British imperial interests in Tibet, Central Asia and the outer frontier zone, while extending, in a nationalistic manner, Indian control and sovereignty in the sub-Himalayan provinces of the inner zone. This has had the effect of simplifying an exceedingly complex internal administrative mosaic and strengthening the power of the central government at New Delhi; but it also resulted in a situation whereby the central authority assumed direct responsibility for the surveillance of some 4,000 kilometres of northern frontier, with neither the requisite resources for such a task, nor the necessary intelligence of events in Tibet to permit the most advantageous deployment of those forces which were available. However the ultimate consequences of such political action were by no means immediately apparent to the Indian Government. Post-war relationships with the communist government of China were exceedingly cordial [3]. India was a persistent advocate of Communist China's right to a seat in the United Nations, sympathised with China's attitude when U.N. forces carried the war northward beyond the 38th Parallel in Korea, and condemned the continuance of American pressure on the Pacific seaboard of China. Cultural and technical missions were exchanged between the two countries to study their respective programmes for solving similar economic problems, and Mr Nehru continually stressed the importance of Sino-Indian friendship as a key to world peace. In 1954 this period of

political courtship culminated in the enunciation of the so-called *Panchshila*, or Five Principles, of peaceful co-existence and mutual respect for each other's territorial sovereignty, and the signing of an agreement governing Indo-Tibetan commerce and pilgrim traffic. By this Agreement India confirmed that she regarded Tibet as part of the sovereign territory of China and accepted the restriction of Indian traffic to authorised routes, trading posts, and certificated merchants. Chinese trade agencies were to be established at New Delhi, Calcutta and Kalimpong, in return for Indian agencies at Yatung, Gyantse and Gartok. The treaty was hailed in India as a resounding justification of Indian policy of non-alignment in world political conflict. Asia had demonstrated to the West and to her former imperial masters that if reason prevailed communism and democracy could establish a peaceful *modus vivendi*, and by acting thus India had secured her lengthy landward frontier against aggression without a shot being fired, and was able to concentrate on more pressing internal problems. The economic and social reforms being carried out by China in the archaic kingdom of the Dalai Lama were long overdue ; and there was no reason to suppose that the new China would be able to divert any more energy from the problems of her eastern homelands to this barren, remote frontier province than the old China had done.

Unfortunately Indian hopes that this constituted a settlement of frontier issues with the Tibetan region of China have been belied by subsequent events. As Mr Nehru has later revealed, border incidents began almost as soon as the 1954 Agreement was signed, but were kept secret on the grounds that it would serve no useful purpose to make public such minor disagreements when major issues were being settled so amicably. When Chou En Lai visited India in 1956 he informed Nehru of Chinese proposals for the settlement of Sino-Burmese border disputes, but made no mention of possible difficulties in the interpretation of the Sino-Indian border – from which the Indian leader concluded that the incidents which had occurred in the Himalayan frontier district of Bara Hoti in Uttar Pradesh were of no more than local significance. However, the more suspicious India became of China's interpretation of the concept of Tibetan regional autonomy and of the activities of Chinese forces along the Tibetan border, the closer became her surveillance of the frontier. Patrols sent in to more remote northern tracts of the frontier zone were confronted by Chinese troops in occupation of territories which India considered to be rightfully hers, and in several cases were roughly handled. As surveillance intensified in the period leading up to and following the flight of the Dalai Lama to India, border incidents multiplied and eventually led to armed clashes and bloodshed. At this stage it was no longer possible to withhold knowledge of events from the general public and the Indian Government has since published notes, memoranda and letters exchanged by India and China on this issue from 1954 onwards [4].

The political reactions in India to this revelation of Chinese aggression do not concern us here. Our chief concern is with the realities of the geopolitical situation revealed by these documents and frontier events. In the first place is apparent that the speed and ruthlessness of the Chinese occupation of Tibet, and the surge of Chinese forces

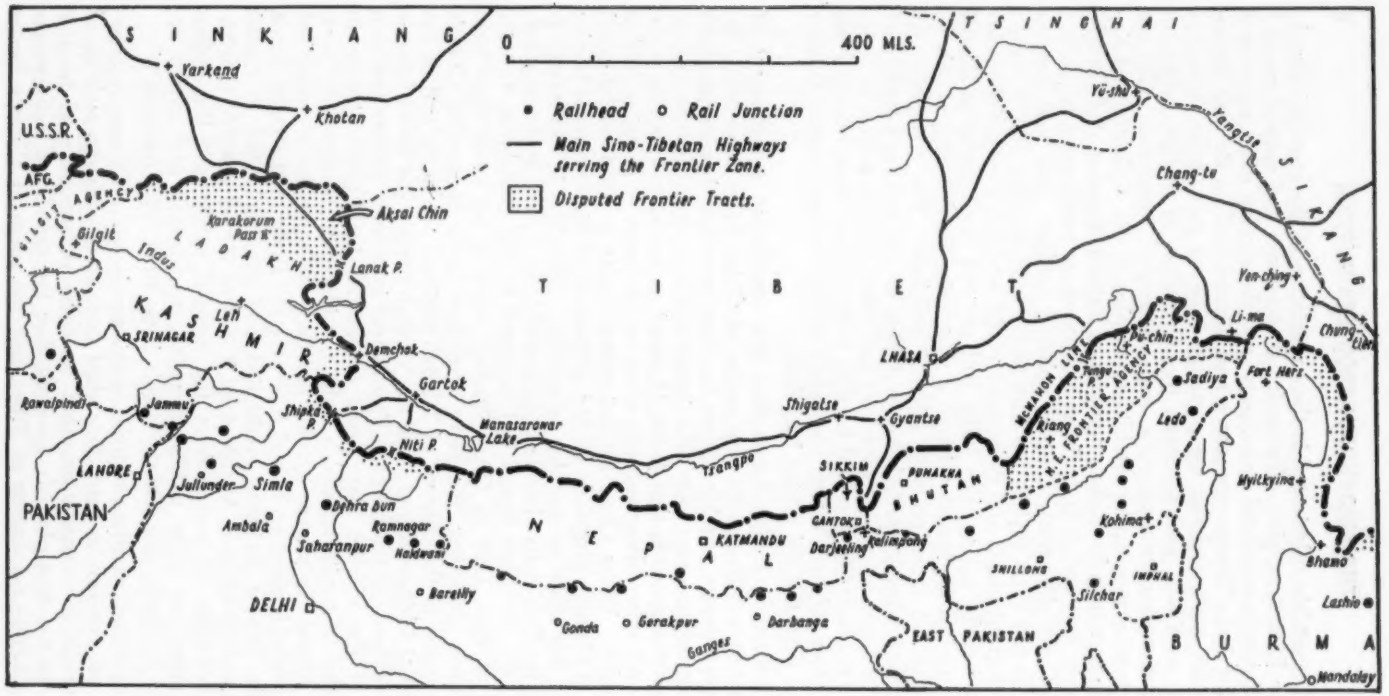


Fig. 1. Showing the Main Sino-Indian boundary as represented in British Maps of 1946; the present disputed terrains; and strategic transport pattern, including the approximate alignment of new highway constructed by the Chinese in Tibet.

to the frontier, took the Indian Government completely by surprise. The barrier of an ancient Buddhist Kingdom and deeply religious people proved to be no barrier at all before the militant onslaught of communist armies and political propaganda. Blocked by American power on the Pacific seabord, China had turned inland to divert attention from domestic difficulties and provide an outlet for the excess energy of her vast forces and manpower in the resurrection and economic development of the ancient Chinese Empire in Inner Asia. It is difficult otherwise to account for the almost maniacal urgency with which roads have been built and physical obstacles overcome to attach these outlying provinces to the Chinese homelands and deny alternative orientation. Late in 1952 the Sikang-Tibet highway was opened to traffic as far as Chang-tu and the Chang-tu (Chamdo) area was removed from Tibetan administration. In December 1954 it was announced that two military highways had been completed from China to Tibet, one *via* Sikang and one *via* Tsinghai, bringing Lhasa within twenty days journey from Peking or Shanghai in contrast to three months by normal caravan traffic. In March 1956 Peking reported that a route had been found for a highway 1,300 kilometres long from Lhasa to Gartok in Western Tibet which would allow perennial motor traffic, instead of the customary procedure of making the journey in one direction during the period May-July of one year and returning during the same months the following year. About the same time it was announced that a road from Sinkiang province to connect with this Lhasa road would be commenced in 1956. It would appear that both of these roads have now been completed and their approximate alignment is shown in Figure 1. In 1956 a Peking-Lhasa air service on a ten-hour schedule came into operation, and military airfields have been constructed in various parts of the Tibetan plateau. A railway has also been planned which will run from Lanchow to Lhasa, crossing the Tsinghai Province of Inner Tibet where Chinese geologists claim to have discovered oilfields, in the Tsaidam basin, as rich as those already found in nearby Yumen. Preliminary reports on the mineral wealth of Tibet have led the Chinese government to plan the development of local copper, iron, cement and chemical industries [5], while there is some evidence that exploitation of forests on the margins of the Tibetan plateau has already begun. Experimental farms set up by the Chinese army have revealed the possibilities of Chinese colonisation, and as early as 1956 Peking announced that it was China's intention to increase the population of the province from the existing 2-3 million to at least 10 million. In the light of such developments it is difficult to credit that it was only some twenty years ago that Professor Kenneth Mason was extolling the value of the Himalayas as a barrier to modern communications and telling the Royal Geographical Society that "Political and physical obstacles combine with technical difficulties to prevent air development across this barrier.... and until we can cross it in artificially warmed, multiple-engined air liners with a ceiling of 40,000 feet in one 'hop' of a thousand miles or so, I see no prospect of air development" [6]. It serves as yet another reminder of the fact that the strength of a natural barrier is ultimately but a function of the technical capabilities and energy of the communities it divides.

Thus by their mutual annexation of former buffer zones India and China have, for the first time, come into direct territorial contact and are faced with the problem of precise boundary delimitation. Under the British zonal system this problem never arose with urgency, since the British Raj was more concerned with recording the northern limits of its own direct administrative responsibility than the accurate delimitation of boundaries between buffer states. Furthermore in many sections of the mountains demarcation of boundaries was prohibited by the nature of the country. Consequently the central Himalayan system of boundaries was never subjected to that degree of rigorous scrutiny, over-all survey and physical demarcation which characterised the work of boundary commissions on the North-west Frontier, where the threat of Russian expansion made this necessary. Unfortunately under present circumstances such lack of precision has afforded China the opportunity of challenging the legality of Indian claims to certain territories on the borders of Tibet, and by actually occupying some of them has placed the onus on India to substantiate such claims either by force or negotiation.

The Chinese case as revealed in letters of Chou En Lai to Nehru may be summarised as follows :—

(1) The boundary question is a legacy of the period of British aggression on Tibet. Now that China is strong enough to support her ancient suzerainty she takes up the issue where it was left by Britain, and does not accept, as India does, the results of that aggression. The boundary must be negotiated anew between the two non-imperialist powers, India and China.

(2) The Sino - Indian frontier has never been formally delimited. Although at various times British India attempted to impose on Chinese Tibet delimitations of different sections of the boundary, these were never agreed to or ratified by China. Thus in the 1842 treaty between Kashmir and Tibet, China took no part in the negotiations, and in any case the boundary between Ladakh and Tibet was never precisely defined, the treaty merely stating in general terms that Tibet and Kashmir would abide by their borders, without making clear what these were. In drawing this boundary Chinese cartographers have usually followed a line similar to that laid down in John Walker's *Map of the Punjab, W. Himalaya and adjoining Parts of Tibet* compiled for the East India Company and attached to Alexander Cunningham's book *Ladakh*, 1854, whereas British Indian maps have included large sections of territory outside this line. The road built by China across the Aksai Chin area of Ladakh thus lies wholly within Chinese territory and border incidents in this area have resulted from the trespass of armed Indian patrols across the boundary. Similarly, the boundary between the Ari area of South-west Tibet and the Punjab-United Provinces hill states has never been delimited. Indeed in the nineteen-twenties there was a constant erosion of Tibetan territory along this front as a result of British expansion, and although Tibetan authorities complained of this administrative ingress, they never gained redressal. As to the so-called McMahon Line east of Bhutan, the Chinese Government has repeatedly pointed out to both India and Burma that this was a direct result of British aggression, has never been recognised by any Chinese Central Government and hence is illegal. Its illegality is demonstrated by the fact that even Britain did not dare make public the conditons of the Simla Conference of 1913-14 for a considerable period [7], nor depict the McMahon Line therein defined on official maps until 1937. Maps of *Tibet and Adjacent Countries* published by the Survey of India in 1917 and later, and a map in the 1929 Edition of *Encyclopaedia Britannica*, show the boundary running along the base of the mountains in Assam — the alignment followed by Chinese maps. The tribal country between the skirt of the hills and the McMahon Line belongs to Chinese Tibet, and it was only in 1951 that Indian troops advanced on a large scale into the area south of the McMahon Line—at a time when China was liberating Tibet.

(3) Although it is clear from this that the boundary has not been formally delimited, and, as depicted on British Indian maps, is the result of unilateral and

hence illegal alteration, China recognises the reality of Indian aspirations and rights in some of this territory, and in view of Sino-Indian friendship is prepared to negotiate a formal delimitation. China, however, cannot understand Indian criticism of the manner in which Chinese maps show the boundary, nor will it condone imperialist-inspired Indian aggression on Chinese territory. Such provocation would be 'neither wise nor worthy'.

(4) China does not regard the boundaries of Sikkim, Bhutan or Nepal as falling within the scope of the present discussion. "China is willing to live together in friendship with Sikkim and Bhutan, without committing aggression against each to other, and has always respected the proper relations between them and India".

The Indian reply to this case runs as follows :—

(1) India never has had imperialistic intentions towards Tibet, and in the decade following independence demonstrated this by surrendering former British rights in that territory and subscribing to the 1954 Agreement. Nevertheless "The independence and integrity of India are what the Indian people laboured for during their long struggle for freedom and they cannot permit any injury to or infringement of them". The territories she claims, are Indian by right of "history, geography, custom and tradition", not as a result of British aggression against China.

(2) While it is true that the Sino-Indian boundary has not been formally delimited along its entire length, nevertheless it has been generally accepted by custom and administration. In the case of Ladakh the boundaries with Tibet referred to in the 1842 (Kashmir) Agreement were well known and in fact had been marked by stone cairns in 1687 after the final expulsion of the Mongols. Representatives of both the Dalai Lama and the Emperor of China signed the 1842 treaty and later Chinese officials had been quite satisfied with the border arrangements. Commercial and other provisions of the treaty had indeed been operative right up to 1946 without complaint. Walker's map quoted by the Chinese government was based on a *Map of Ladakh and Nari Khorsum*, by Capt H. Strachey who toured part of Ladakh in 1847-8 but never visited the Aksai Chin area. The first accurate maps of Ladakh only became available after 1865, and since 1867-8 official Survey of India maps have shown the boundary where it now is. Drew, Governor of Ladakh under the Maharajah of Kashmir, officially inspected the northern frontier in 1871, and the maps appended to his book *Jammu and Kashmir Territories*, 1875, show the course of the boundary quite clearly. Chinese maps on the other hand varied in the delineation of the boundary, the official map of 1893, for example, showing Aksai Chin as part of Kashmir, and the *New Atlas of China* published by Shun Pao in 1935 placing a considerable section of the Chang Chenmo area on the Indian side of the border. As late as 1956 Chinese maps show the boundary dissecting Pangong Lake.

Similarly, although lacking formal delimitation, there is little doubt as to the recognised course of the Himalayan border of Himachal Pradesh and Uttar Pradesh. The six passes (Shipki La; Mana; Niti; Kungri Bingri; Darma; Lipu Lekh) authorised for Indo-Tibet trade by the 1954 Sino-Indian Agreement in fact are boundary passes, and India has always controlled the southern end of these passes.

The McMahon Line, first recorded in maps accompanying the *Simla Convention* (1914), was only one boundary discussed by that conference. It also attempted to define the boundaries between Inner and Outer Tibet and China. The reason for the British delay in publishing the Convention was that, in spite of the Chinese representative at the conference initialling the complete document, the central government of China objected to the latter two boundaries, and Britain hoped to obtain Chinese agreement on the question of Inner Tibet before publication of the treaty as a whole. At no time did China object to the definition of a McMahon Line. In the actual delimitation of the line by McMahon a digression was made at Migyitun to leave the village and two sacred lakes of Tsari Sarpa and Tso Karpo in Tibet for the convenience of Tibetan pilgrims ; but in general the line follows natural features, principally the watershed of the main Himalayan range, and as such is clearly indicated on modern maps, even if physical demarcation was prohibited by the nature of the country. It is wrong to assume that, because earlier British maps merely indicated the northern limits of actual administration, the major political boundary of India did not follow this great divide. This is an ancient frontier, substantiated by historical and cultural orientation, to which British administration eventually extended. Even so it must be remember-

ed that British Indian agreements with the tribes of this territory were made as early as the middle of the nineteenth century and that the Sadiya and Balipara Frontier Tracts of the North-east Frontier Agency were constituted in 1912-13, before the Simla Conference. This was not an arbitrary line imposed on Tibet, but a natural, ethnic and administrative boundary, defined with some precision by Bailey's survey of 1913-14 and McMahon's delimitation.

(3) In spite of Chinese protestations of peace with Sikkim and Bhutan, Chinese maps show considerable tracts of Bhutan as Tibetan territory and there have been communist accusations that both these states were the result of British aggression against Tibet. India reminds China that both kingdoms are under Indian protection and boundary disputes with them must involve India. In the case of Sikkim the boundary with Tibet was defined by the *Convention of 1890* in which China recognised that the Government of India had exclusive control over Sikkim's external relations, and in 1895 the boundary was actually demarcated.

(4) The fact that China has had many opportunities in the past to raise these objections to the boundaries of India but failed to do so can be taken as indirect confirmation of her general recognition of their alignment. That China was militarily weak at the time is no excuse, as this in itself would not prevent the making of verbal protests, and indeed did not do so in other cases. After such a lapse of time, and in the face of actual Indian administration of these territories, the sudden *volte-face* can only be regarded as aggression against India by a power that has suddenly become aware of the fact that she holds a regional military advantage and is seeking to exploit it.

However much one sympathises with the Indian point of view geographical realities must be recognised, and, if the Indian case is to be put as strongly as possible, it must first be divested of certain geographical overstatements engendered by nationalist reactions against Chinese betrayal of the Sino-Indian pact of friendship. In the first place it must be recognised that the Himalayan area has functioned in the past not merely as a barrier separating circumambient riverain communities, but as a geographical region in its own right. It has received peoples and cultures from many directions, and at various times, but has imposed upon them its own peculiar regime born of the unity of the high places. At times it has afforded a cultural link between peripheral civilisations. At times it has grown sufficiently powerful to impose its will on the surrounding lowlands, while at other periods it has paid homage to alternate lowland empires. Its leaders have sometimes sought refuge in China, sometimes in India, while it in turn has sheltered refugees from all sides. From these various experiences it has usually emerged chastened and changed, but still different from adjacent regions. Neither China nor India can claim exclusive apparentage to Himalayan societies. Indeed China admits that, in spite of their Mongoloid characteristics, Tibetan folk are quite different from the Han peoples of China proper. Thus Indian statements such as :—

"The water-parting formed by the crest of the Himalayas is the natural frontier which has been accepted for centuries as the boundary by the peoples on both sides". and "It is true that the British occupied and ruled the Indian subcontinent against the wishes of the Indian people. The boundaries of India were, however, settled for centuries by history, geography, custom and tradition",

and attempts to prove that the Monbas, Abors, Akas, Daflas and other tribes of the North-east Frontier Agency, let alone the Ladakhis of North Kashmir, are Indian in the old cultural sense of the word weaken rather than strengthen India's case. The communal and cultural principles which were applied in the subdivision of British India do not obtain in this dispute. If it had been so then India would have had as much right as China to lay claim to the Tibetan cultural hearthlands. By acknowledging that Tibet was part of the sovereign territory of

China, India announced that she was playing the game of Himalayan partition according to political rules, and thus, whether or not she is dubbed imperialist in the process, her case must be based ultimately on her position as successor state to British India, – on political, jurisdictional, administrative and territorial rather than on cultural grounds. The fact that the North-east Frontier Agency was created and administered by British Indian political officers up to the McMahon Line is a more important consideration in this context than whether the Abors are Tibetan or Indian in cultural affinity, or where the 'natural' frontier or racial divide is located, or indeed whether Asokan inscriptions prove this to have been Mauryan territory over two millenia ago.

Since the Himalayan political system established by British administrators was a complex one, it follows that the degree of certainty with which the course of the boundary can be politically substantiated varies section to section. There is no over-all authority for its delimitation—certainly not small-scale atlas maps or private publications such as *Encyclopaedia Britannica*. The weakness of such evidence becomes apparent when it is realised that the thickness of the boundary symbol itself on such maps is often sufficient to cover the actually disputed terrain, and that the 1929 Edition of *Encyclopaedia Britannica*, quoted by the Chinese in support of their claims on the Assam front also clearly shows Aksai Chin as part of Kashmir. The value of cartographic evidence in international boundary disputes rests ultimately on the degree of accuracy of topographic survey obtaining at the date of its compilation, the extent to which it represents the official point-of-view of the state concerned, and the measure of its conformity with the principles of delimitation laid down in the definitive treaties. Indeed, in many cases where disputes have arisen from conflicting cartographic interpretations of boundary alignments, arbitration tribunals have regarded the boundaries depicted on the official maps of the contestant states as merely convenient devices for exhibiting their maximum territorial claims [8], and have been more powerfully influenced in their deliberations by proof of uncontested territorial occupation and administration by a particular state.

On this type of evidence it is possible to distinguish between two sections of the Sino-Indian boundary, (I) the 2,500 km. section from the Dihang area in the east to the vicinity of the Shipki Pass in the west, and (II) the sinuous 1,500 km. section traversing the Western Himalayas from Shipki to the borders of Afghanistan.

With regard to the first section the Indian case is particularly strong, for, in opposition to ill-defined Chinese cartographic claims, India can advance material proof of political and administrative control over a considerable period, and justifiably point to lack of specific Chinese objections to the McMahon Line until recent times. Indeed, notwithstanding their considerable military advantage, Chinese forces have transgressed the official Indian boundary at only one or two places such as Longju south of Migyitun and Bara-hoti in Uttar Pradesh, and even then to no great depth. Furthermore it can be demonstrated that, whatever their past cultural history, the frontier tracts of the southern Himalayan glacis are now economically linked to India and the Indian transport system. An integrated crest-cum-watershed boundary, running

along the Great Himalayan Range much as it does at present, would thus appear to accord with existing political and economic conditions as well as representing in a reasonable manner original treaty obligations and intentions.

For the second section of the boundary however the Indian case is not so well-documented. Even modern official maps of this section exhibit inconsistencies and indicate certain stretches of boundary as 'undefined'. Indeed whereas British maps of 1945-46 (e.g. *G.S.G.S. Hind. 1050. 1:5m. 1946, drawn by Survey of India.*) show the Ladakh boundary with Sinkiang as following the Karakash valley and Kuen Lun range, the most recent Indian publications (e.g. political map appended to *Indian Ministry of External Affairs. White Paper No.2. 1959.*) have this boundary following the Karakorum range, *via* the Karakorum Pass seventy miles to the south, and are thus obliged to make it swing abruptly north-eastward to include the disputed Aksai Chin area. While in the west this alignment closely conforms with the Indus-Sinkiang watershed, extension of this defining principle eastward would weaken Indian claims to Aksai Chin. A more serious weakness, however, is revealed by the fact that China was able to construct a 100-mile highway across this area in 1956—without India being aware of it. Indian administration and 'effective occupation' of this remote, thinly populated tract is difficult and intermittent due to seasonal restriction of movement, and this was recognised by Nehru's proposal of the 16th of November 1959 that India will withdraw west of the boundary line shown in Chinese maps of 1956 if China will withdraw east of the traditional line of Indian maps, to leave a broad no-man's-land for future negotiation. This would appear to be a more reasonable request than Chou En Lai's earlier proposal that each side should withdraw 20 km. from the line to which it 'exercises *actual* control in the west' In this area Chinese forces have already made substantial inroads into Indian territory and a withdrawal of this order would still leave them inside the traditional Indian borders. Nevertheless it would appear necessary to negotiate some form of '*zone of disengagement*' in this section if border clashes are to be avoided while the boundary is formally and peacefully delimited. The same necessity does not arise in the case of the first section described above, apart from the few points of actual collision.

A final point may be made with regard to the western section of the boundary. In the main it constitutes the northern and eastern borders of the former state of Kashmir, and while Indian statesmen and maps depict this as traditional Indian territory in their case against China, it is not universally so regarded [9]. The inroad of Chinese forces here is yet a further reminder that a solution of the Indo-Pakistan dispute over Kashmir is long overdue. Unless these two successor states to British India sink their differences in the face of the Communist threat from Central Asia, they will have little left to quarrel about. The creation of air bases in Tibet, the improvement of lateral communications in Central Asia, and the rapid construction of roads in Afghanistan by Russian engineers bodes ill for the future security of the entire northern littoral of the Indian Ocean—and in this not only India and Pakistan but the whole free world is concerned.

[1] See for example, Buffer States — Their historic service to Peace. *Round Table*, 1954-55, XLV : 334-345.

[2] See Mark C. Feer. India's Himalayan Frontier. *Far Eastern Survey*, 1953, XXII : 137-141.

[3] For a scholarly attempt to provide Sino-Indian friendship with a lengthy history see K. M. Panikkar. *India and China*. Calcutta, 1957. Cf. however Shao Chuan Leng. India and China. *Far Eastern Survey*. 1952, XXI : 73-78.

[4] The most important publications are two White Papers issued by the Ministry of External Affairs, Government of India. *White Paper I. Notes, Memoranda, and Letters exchanged and Agreements signed between the Governments of India and China 1954—1959* and *White Paper II. Notes, Memoranda etc. Sept.-Nov. 1959 and A note on the Historical Background of the Himalayan Frontier of India* (With map). New Delhi, 1959. In addition a number of individual letters of Nehru and Chou En Lai have been published separately.

[5] Reported in Peking Magazine *China Reconstructs*, Nov-Dec, 1954.

[6] Mason Kenneth. The Himalaya as a barrier to Modern Communications. *Geogr. J.* 1936, LXXXVII : 1-16.

[7] The Simla Convention was published in the 1929-Edition of Aitchison's *Treaties*.

[8] Cf. Hyde, C. C. Maps as evidence in International Boundary Disputes. *Amer. J. of Int. Law*. 1933, 27 : 311-316.

[9] See Mayfield, Robert C. A Geographic Study of the Kashmir Issue. *Geog. Rev.* 1955, 45 : 181-196.

THE INTERNATIONAL CARTOGRAPHIC ASSOCIATION

A conference for international collaboration in cartography took place in Bern on the 9th and 10th of June, 1959. This conference arose as the result of preparatory work during the previous three years and, as a consequence of it, the *International Cartographic Association* has come into existence which represents the national cartographic organisations of the member countries.

On the personal initiative of Dr Carl M : son Mannerfelt, formely of Stockholm University and now Managing Director of Generalstabens Litografiska Anstalt, the cartographic division of Esselte, a conference on applied cartography was held in July and August, 1956, in Stockholm. Participants of eleven nationalities attended. From this meeting a Committee of Six was appointed with the task of investigating the possibility of organising an international cartographic association. Dr Mannerfelt was elected chairman and the other members were :— Mr K. W. Bland (*U.K.*), Mr S. de Brommer (*France*), Dr D. Chervet (*Switzerland*), Mr Duncan Fitchet (*U.S.A.*), and Dr E. Gigas (*Germany*). This committee met in Bern and Lausanne on June the 5th and 6th, 1957.

The next meeting, on a large scale, took place in Chicago, in June 1958, at the invitation of Messrs Rand McNally. Cartographers from eight countries were invited to take part in this Second International Cartographic Conference. At this conference the Committee of Six proposed to invite to a further meeting, one representative from each of the established national cartographic committees or societies ; one from the American Congress of Surveying and Mapping and one national representative from those countries represented on the Committee of Six. This meeting was held in Mainz on the initiative of the German Cartographic Society, on the 14th of November, 1958. The United Kingdom was represented by Brigadier L. J. Harris, O.B.E.

This meeting was followed by last year's conference in Bern. Official delegates came to this conference from Austria, Belgium, Finland, France, Germany (West), Italy, Netherlands, Norway, Spain, Sweden, Switzerland, U.K. and U.S.A. The representative from Portugal at the last moment was unable to attend. The delegates voted unanimously for the creation of an organisation with the purpose of developing international co-operation in cartography and with a view to affiliation with the International Geographical Union on the condition of remaining autonomous.

The proposed affiliation with the International Geographical Union will be put to the XIXth International Geographical Congress which will take place in August, 1960, in Stockholm.

HILLSHADING FOR RELIEF DEPICTION IN TOPOGRAPHICAL MAPS

WITH SOME RECENT APPLICATIONS

L. J. HARRIS, O.B.E.

This paper was originally presented at the Commonwealth Officer's Conference at Cambridge, 1959.

DURING the last three years the Ordnance Survey has published four tourist maps at the one-inch-to-one-mile scale in which hillshading has been employed to assist in the depiction of ground relief. Hillshading in this context is taken to mean the use of shadow-tones to give or to improve the impression of ground relief, creating the optical illusion of the third dimension making the hills, so to speak, stand out in relief.

The maps are the *Peak District*, the *North York Moors*, the *Lake District*, and *Lorn and Lochaber*. In the first two a simple shadow-tone in blue has been overprinted on a layer-tinted map, while in the other two maps a more naturalistic appearance is attempted by omitting the layer-tints and using more shadow-tones. In each of these maps the shadows are those which would be cast by the rays of a north-west light inclined at an angle of about 45 degrees with the ground, and have been drawn by hand.

The use of hillshading to depict ground relief in maps is not new. Over 150 years ago there was much activity in England, France and elsewhere in developing techniques of hillshading. In England "shading as from a vertical or zenithal light" was adopted, the direction being altered to "near-zenithal" towards the middle of the century, while in France "shading as from an oblique light" from the west, at an angle of about 45 degrees with the ground was adopted. There is much to be learnt from a study of the opinions then held [1].

"Hillshading from a zenithal light" in its first application in the one-inch map– the map of *Kent*– published on the 1st of January 1801, was little more than "slope-shading", the intensities of the shadows being inversely proportional to the amount of light reflected upwards from the ground when illuminated by a zenithal light. There were three stages in the procedure, the first stage being the preparation of a "hill-sketch" by the surveyor. The surveyor or hill-sketcher, working from vantage point to vantage point in the field, drew on the plan or map horizontal lines, which can be likened to formlines at a close vertical interval, to indicate by their density the degree of slope. In the second stage the hill-sketches were passed to the hill draughtsman in the drawing office who, treating the map sheet as a whole, prepared the "hilldrawing". The "hilldrawing" was used by the engraver in the third stage for the engraving of the hachures or vertical shading lines on the copper printing plate of the final map. It is worth noting that the relief information was obtained by the hill-sketcher from a study of the ground. He had been taught to "apprehend" land forms and hill shapes correctly and was able, it is said, to assess slopes to about one degree. Consistency between the sketches of different

surveyors was achieved by providing each surveyor with a scale of shades for slope-shading. There were many scales of shades in use. In Germany, Major Lehman produced a scale in steps of 5 degrees up to 45 degrees for vertical hachures, while in England Captain H. Y. D. Scott, R.E., produced a scale for horizontal shading-lines for slopes from 0 to 35 degrees. Later in the century a scale of shades was devised by the then "United States Coast Survey" for slopes from 0 to 90 degrees.

But a map in which "slope-shading" alone is used for the depiction of relief does not, in spite of the addition of spot heights, readily give an impression of the relative heights of the ground features, nor does it give a naturalistic picture of the ground. For these reasons the principle of "aerial perspective" was introduced into the hillshading in the Ordnance Survey maps early in the nineteenth century, and in the development of its application much is due to Mr Robert Dawson (1776-1860), a surveyor of exceptional artistic ability who joined the Board of Ordnance in 1794.

Dawson was not content with showing slope values only. He tried to view the ground mentally as from above, that is to say to obtain a bird's-eye view, and in accordance with the principle of "aerial perspective", as it was then called, he treated the summits as the foreground of the picture and the low ground as the distance. In the higher mountainous regions dark shades and powerful contrasts were applied, where little detail was obscured, while lighter tones were employed at lower elevations. Thus a drawing of gradated tones was achieved, the tones becoming increasingly softer as the elevation of the ground became less. From the information obtained from the hill-sketches, shadows were added to indicate the steeper slopes, thus giving character to the drawing. But even these additional shadows appear to have been softened as the elevation decreased in accordance with the principle of "aerial perspective". Unfortunately the satisfactory combination of the principle of "aerial perspective" and "slope-shading" required a great deal of skill and only a few draughtsmen were capable of producing a satisfactory "hilldrawing". Further, the printing techniques of the first half of the nineteenth century did not permit a good reproduction of the continuous-tone "hilldrawings". It was necessary to convert them into hachured drawings which were engraved on copper plates for the subsequent printing. Hachure-shading could depict the variations in slope but was not very suitable for showing either absolute or relative heights, although summits could be emphasised by leaving them free from all hachure-shading.

A greater disadvantage of "slope-shading" printed in hachures was that the heavy shading obliterated the detail, which influenced the adoption by the French in 1802 of "hillshading from an oblique light" for relief depiction in their national topographical map. Louis Puissant in his book published in 1820 [2] described the method in the following words :– " .... it consists in imagining that the surface of the earth is illuminated by a pencil of rays inclined at an oblique angle to the horizon .... The shadows should be more or less transparent allowing us to distinguish the objects they enclose .... In relation to an observer facing the North, it is customary to illuminate the land from left to

right and to suppose that the ray of light is at 45 degrees with the horizon. There are occasions when a greater inclination is adopted, in order to reduce the length of the shadows thrown from the summits of mountains on the sides of neighbouring spurs. . . ."

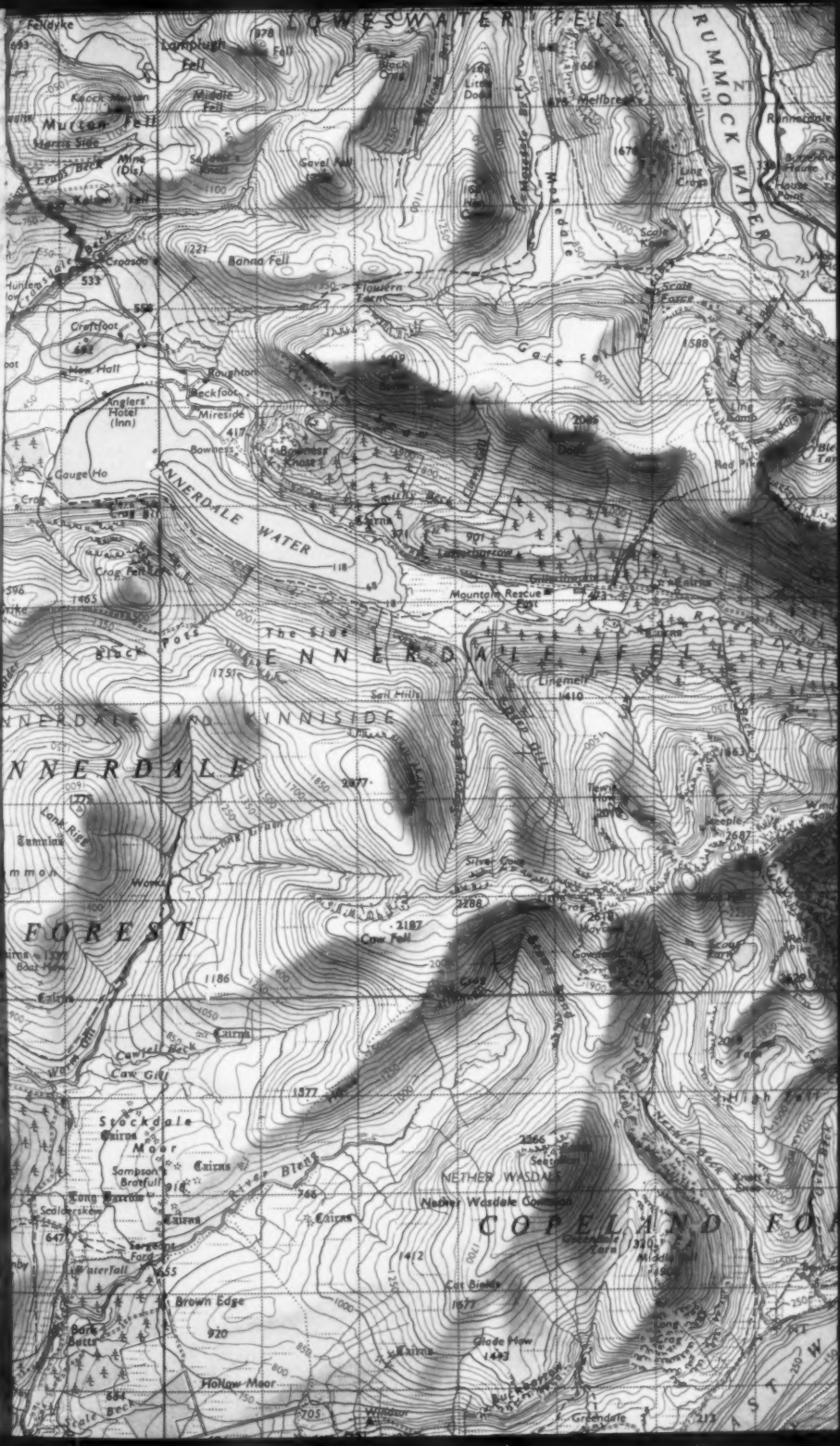
RECENT WORK IN THE ORDNANCE SURVEY

Although the developments in lithographic printing and in colour and half-tone reproduction which permit the printing of transparent tones have today greatly weakened the objections to the system of "hillshading from a zenithal light", great care is still necessary to avoid the loss of detail in the areas of the steeper slopes. The Ordnance Survey in its recent work has only attempted the method of "hillshading from an oblique light", mainly because it is easier to obtain a satisfactory result by this method than by "hillshading from a zenithal light". The shadow from an oblique light falls on one side of the mountain only and requires little colour strength to create an impression of relief, relying for its effect on the contrast with the illuminated side of the mountain. On the other hand, the shadow from the zenithal light relies on the gradations within itself to depict the ground form and demands more colour strength and more drawing ability to create the effect of "aerial perspective" to make the hills stand out in relief.

And in deciding to obtain the shadows by hand-drawing rather than by the photography of a relief model suitably illuminated, regard has been paid to the staff and equipment available, to the need for the quick and easy examination of the work at all stages of its progress, and to the knowledge that even after the photography of a relief model, manual retouching is still necessary to correct false impressions when the line of the hills falls at certain angles to the light.

As already mentioned, two styles of hillshaded maps have been published. In the *North York Moors* style (Map Inset 1), a single-colour shadow-tone in blue has been printed in half-tone over the layer-tinted map and the layer-tints have been chosen so as to reduce the 'step' effect of the layers. The style seems suitable in areas where the ground is of rolling hills and not very high (up to about 2,000 feet) – *e.g.*, the *Peak District*, the *North York Moors*, and the *Wye Valley*. Recent experience has confirmed that there exists enthusiastic support for the retention of layer-tints. Supporters of layer-tints wish to keep them because they give an immediate and positive indication of relative heights.

In the *Lake District* style (Map Inset 2), a naturalistic appearance is sought. There is no layer system. Two printings in purple-grey tones for the shadow side of the hills and one printing in a yellow tone for the illuminated side have been added to the standard one-inch map. The style has appealed to a far wider public than the layered style of the previous edition of this map sheet. It is apparent that the naturalistic appearance of the hillshading has found much favour, and the supporters of the style are content to obtain the relative heights from the colour gradation and the contours. The style is being used in areas of high elevation and of a rugged character, *e.g.*, the *Lake District*, *Lorn and Lochaber*, and *Loch Lomond*.


LOWESWATER FELL
RUMMOCK WATER
Fieldyke
Lamplugh Fell
Knock Mountain
Middle Fell
Mullon Fell
Harris Side
Mine (Dis)
Lewis Beck
Sandy Beck
Gavel Fell
Melbreak
Rannerdale
Banna Fell
Crosscrake
Hunters Crag
Crossgill
Hewthwaite Farm
Scale Force
Gate Fell
Crag Foot
How Hall
Roughton
Beckfoot
Anglers' Hotel (Inn)
Mireside
Bowness
Bowness Knott
Cauge Ho
Crag Hill
Crag Fell
ENNERDALE WATER
Smithy Beck
Lanthwaite Green
Mountain Rescue Post
The Side
ENNERDALE FELL
Black Sail Pass
Sail Hills
Lingmell
ENNERDALE AND KINNISIDE
ENNERDALE
FOREST
Tumma
Wood
Silver Cove
Cairns
Cow Fell
Caw Gill
Stockdale Moor
Sampson's Bratfull Pig
Scalderskew
Foxes
Waterfall
Brown Edge
Bank Betts
Hollow Moor
Stale Beck
Windsor
NETHER WASDALE
Nether Wasdale Common
COPELAND FOREST
Greendale
Middle Fell
Glade How
Long Crag
Buckbarrow
Steeple
High Pots
Wasdale Beck
Knott
Irton Fell

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Map Insert 2 Lake District

Carlton
Faceby
Whorlton
Whorlton Moor
Black Moor
Snilesworth Moor
Arden Great Moor
Hawnby Moor
Bilsdale West Moor
Cold Moor
Chop Gate
Bagdale Fm
Busby Hall
Busby Moor
Crosslands Moor
Wrath
Live Moor
Hatey Moor
Scugdale
Holiday Hd
Proud Hills
Stony Moor
Coal Ridge
Cow Ridge
Arrisgill Ridge
Douglas Ridge
Locker Wood
Ellers Wood
Cow Wath
Arden Hall
Bilsdale
Hawnby
Old Quarries
Whinstones
Limekiln Ho
Little Moor
North Moor
Humble Hill
Faceby Grange
Faceby Lo
Faceby Beck
Goulton Holm
Underhill Ho
Carlton Hall
Manor Ho
Bracken Hill
Great Barmy Cliff
Little Barmy Cliff
Whorlton Ho
Faceby Plane
Hathwaite
Hathwaite Green
Sunny Side
Hollin Hill
Fog Close
Sorrew Hall
Harfa
Harfa Bank
Scugdale Beck
Scugdale Hall
Raikes
Holiday Hd
Wet Moss
Faor Moor
Shooting Ho
Coal Ridge
Stony Moor
Proud Hills
Snilesworth
Snilesworth Lodge
Rye Fm
Low Arrisgill Fm
High Arrisgill Fm
Craig Fm
Miley Pike
Douglas Ridge
Dale Head
Wheat Beck
Low Cote Fm
Plane Tree Hall Fm
Locker Low Wood
Lower Locker
Locker Wood
Bawderie Wood
Scoslenden Fm
Long House Fm
Ridge House Fm
Fox Ho
Cow Wath
Ellers Wood
Brewsters Hill
Fox Pasture Wood
Arden
North Moor
Harland Hog Close
Ings Moor Wood
Humble Hill
Arden Hall
Comb Hill
North Wood
Long Parthys
Broomflat
Thwaites
Long Wood
Staindales
Cleugh
Stone Ingate
Stockhill
Bumpers Fm
Fingo Wife Cote
Cock Flat
High Crosslets
Low Crosslets
West Cote
Esp Hill
Esp Ho
Holiday Beck
Tumulus
Green Tower
Cow Tower
Orterley
Crookleith
Miller's Moor
Head Ho
Flat Horse
Beacon Guest
Cross
Stinghouses
Conisgarth
Low Mill
Stone Ho
Fangdale Beck
Pancil Gill
Sour Milk Hills
High Thwaites
Low Thwaites
Wesher Ho
Sike Ho
Harm House Wood
Hockey Hill
Round Hill
Hazelshaw Ho
Walker Cote
Bumper Castle
Sportsman's Hall
Low Hazel Heads
Moor Gate
Crow Nest
Woolhouse Crag
High Bannerdale
Low Bannerdale
Old Quarry
Bannerdale Wood
Laskill
Timber Holme
Feather Holme
Esp Ho
Tillermire
Akister
Bank Ho
Bransdale Beck
Bransdale
Ukr
Gaskin
Westwood
Broughton Plantns
Salmon's Forest
High Barn
Low Ho
Springs
Mount Ho
Seave Gr
Brind Hall
Stockhill
Cold Moor Cote
Cold Moor Fields
Broomflat
Back Hills
Gaskin
Hawnby Moor
Bilsdale West
Bilsdale West Moor
Hawnby
Faceby
Whorlton
Chop Gate
Snilesworth Moor
Whorlton Moor
Arden Great Moor
Bilsdale
Cold Moor
Live Moor
Crosslands Moor
Wrath
Hatey Moor
Scugdale
Proud Hills
Stony Moor
Coal Ridge
Cow Ridge
Arrisgill Ridge
Douglas Ridge
Locker Wood
Ellers Wood
Cow Wath
Arden Hall
Bilsdale
Hawnby
Old Quarries
Whinstones
Limekiln Ho
Little Moor
North Moor
Humble Hill
Faceby Grange
Faceby Lo
Faceby Beck
Goulton Holm
Underhill Ho
Carlton Hall
Manor Ho
Bracken Hill
Great Barmy Cliff
Little Barmy Cliff
Whorlton Ho
Faceby Plane
Hathwaite
Hathwaite Green
Sunny Side
Hollin Hill
Fog Close
Sorrew Hall
Harfa
Harfa Bank
Scugdale Beck
Scugdale Hall
Raikes
Holiday Hd
Wet Moss
Faor Moor
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Snilesworth Lodge
Rye Fm
Low Arrisgill Fm
High Arrisgill Fm
Craig Fm
Miley Pike
Douglas Ridge
Dale Head
Wheat Beck
Low Cote Fm
Plane Tree Hall Fm
Locker Low Wood
Lower Locker
Locker Wood
Bawderie Wood
Scoslenden Fm
Long House Fm
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Fox Ho
Cow Wath
Ellers Wood
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Humble Hill
Arden Hall
Comb Hill
North Wood
Long Parthys
Broomflat
Thwaites
Long Wood
Staindales
Cleugh
Stone Ingate
Stockhill
Bumpers Fm
Fingo Wife Cote
Cock Flat
High Crosslets
Low Crosslets
West Cote
Esp Hill
Esp Ho
Holiday Beck
Tumulus
Green Tower
Cow Tower
Orterley
Crookleith
Miller's Moor
Head Ho
Flat Horse
Beacon Guest
Cross
Stinghouses
Conisgarth
Low Mill
Stone Ho
Fangdale Beck
Pancil Gill
Sour Milk Hills
High Thwaites
Low Thwaites
Wesher Ho
Sike Ho
Harm House Wood
Hockey Hill
Round Hill
Hazelshaw Ho
Walker Cote
Bumper Castle
Sportsman's Hall
Low Hazel Heads
Moor Gate
Crow Nest
Woolhouse Crag
High Bannerdale
Low Bannerdale
Old Quarry
Bannerdale Wood
Laskill
Timber Holme
Feather Holme
Esp Ho
Tillermire
Akister
Bank Ho
Bransdale Beck
Bransdale
Ukr
Gaskin
Westwood
Broughton Plantns
Salmon's Forest
High Barn
Low Ho
Springs
Mount Ho
Seave Gr
Brind Hall
Stockhill
Cold Moor Cote
Cold Moor Fields
Broomflat
Back Hills
Gaskin
Hawnby Moor
Bilsdale West
Bilsdale West Moor
Hawnby
Faceby
Whorlton
Chop Gate

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Map Insert 1 North York Moors

The naturalistic method of the *Lake District* style is the more complicated of the two and it is felt that it will suffice to consider the procedure for this style in order to bring out the important points of the production technique.

The procedure consists of the following stages :—

(a) To make a sketch in pencil of the shadows at the scale of one-inch-to-one-mile on a blue key of contours and water printed on chart paper.

(b) Using this sketch as a model, to draw with an airbrush in black ink the final hill-shadow drawing on Whatman paper mounted on an aluminium plate and carrying a printing of the contours and water in blue.

(c) To make two continuous-tone glass negatives, one showing the whole tonal range of shadows and the other showing only the heavier shadows normally in the higher altitudes, and to retouch these negatives where necessary.

(d) From these continuous-tone negatives, to make two half-tone positives from which the printing plates are made.

(e) To make the sunny-side mask, then the half-tone sunny-side positive and then the printing plate.

Care is necessary in both the drawing and the photo-litho procedures to achieve certain requirements if a satisfactory result is to be obtained. These requirements can be summarised as follows :

Accuracy in the limits of the shadow. The draughtsman can obtain a good indication of the limits of the shadow from a study of the contours, and he can very quickly draw in pencil the contours on the shadow side to produce a clearly defined shadow area. In order to give a true impression of the ground-shape of certain features, the draughtsman may sometimes need to change locally the direction of the imaginary light.

Accuracy in the hill-top shapes. The contours give only a rough indication of the hill-top shapes. To produce a true picture of the hill-top shapes a more detailed picture of the ground is needed, such as was available to the hill-sketcher of 100 years ago. Fortunately air photography makes that task less laborious than it was, and stereoscopic air-photographs should be used whenever they can be obtained.

Gradation in the drawing. Apart from the distinction between the hill-tops and the valleys by highlighting the hill-tops and applying a tone to the valleys, a gradated tone should be used to distinguish the higher elevations from the lower by applying the principle of "aerial perspective". The tone is made weaker with decreasing elevation both on the shadow and on the illuminated side, and within the tonal range thus produced, the steeper slopes should be distinguished by additional shading, thus giving character to the drawing.

Choice of colour to accord with nature. The principle of "aerial perspective", as it was called even in Dawson's day, should be followed in choosing the colours of the hillshading. On the shadow side, purple in the higher elevations is gradually changed to grey-blue as the elevation decreases, while on the illuminated side, the yellow of the high ground is made paler as the elevation grows less. In addition, the higher hill-tops and hill-crests are highlighted by leaving them uncoloured, to an extent which is dependent on the height and shape of the hill-top or hill-crest.

The selection of the colours for use in the shadow tones needs to be done with the greatest care. A slight change in the colour intensity of the shadows has a great effect on the general appearance of the map. In all the hillshaded maps so far produced, the selection of the colours was made on the proofing press, proofs being pulled in different strengths of colours until the best result for that particular map was obtained. The shadows were kept transparent, so that the detail underneath, *i.e.*, the rock features, the footpaths, and the contours, was not obscured. The overall effect was intended to be in keeping with the appearance of the ground in nature, at least in one of its moods.

For the shadows, light-browns, purples, violets, blues and greys are suitable colours because they can be kept transparent and are often seen in nature in distant views and in shadows. Some shadow colours are more suitable for one type of country than for another, but the yellow tone of the illuminated or sunny side will normally suit all types of country. In the lowlying ground, particularly

in the flat alluvial plains and valleys, a light-green tint is most suitable and has been used in the tourist maps, green being the popular notion of the lowlying countryside in this part of the world. The aim should be to give the map a naturalistic appearance.

In certain types of country the system of the oblique light gives a false picture. If the system were applied to a map covering the boundary between Palestine and Transjordan which runs due north and south, one side of the Jordan valley would be shaded while the other side, the east side, would be illuminated and its character would not be apparent. Generally in any area of rolling country cut by deep valleys running north and south, shadows from an oblique light from a westerly direction may give a false or limited impression. In such cases the alternative of hillshading from a zenithal light may give a better result.

In the sheets of the First Edition of the one-inch map of the Ordnance Survey published after about 1840, when the direction of the illumination had been changed from the zenith to the near-zenith, a very satisfactory impression of ground-relief was obtained from the combination of the principles of "aerial perspective" and "slope-shading", in spite of the difficulties of working in hachures and in one colour only. The improvements made since those times in photo-litho techniques and in colour reproduction greatly simplify the task of applying the system of "hillshading from a near-zenithal light" to topographical maps, as it is easier to ensure transparency in the shadows and it is not difficult to obtain a satisfactory depiction of the slopes. But it is still difficult to introduce the necessary gradation in the shadows to show relative heights. Layer tints can be used to assist in solving this problem and a modification of the technique used in the *North York Moors* map may provide the answer, suitably coloured layer-tints being used to give the relative heights, and hillshading to give the character of the slopes. The Ordnance Survey is studying this idea and may well use it in one of the later tourist maps to be published.

It is possible to obtain this type of "shading from a near-zenithal light" by the photography of a translucent model, a technique which has been demonstrated by the firm of Wever & Co., of Essen. The technique consists of photographing a model made from a translucent plastic polyester which is illuminated from behind by a light inclined at an angle of 10 degrees from the vertical to the model. Two negatives are made, one with illumination from a bright light which is printed in blue-grey and one with illumination from a more subdued light and printed in brown. The use of the two negatives makes it possible for the steeper slopes to be emphasised. The image is formed by the effect of *refraction* on the intensity of the light passing through the model as distinct from the image formed by the *reflection* of light in the more common technique of photographing a plaster model illuminated by an oblique light. It is interesting that the direction of illumination is similar to that advocated in the Ordnance Survey about 1840.

POSSIBLE APPLICATION IN UNDERDEVELOPED COUNTRIES

In the task of mapping the less-developed areas of the world, the surveyor and map-maker find that the effort required to provide the contours is many times greater than the effort to provide the plan-

imetry. The control required for contouring is laborious to establish and is expensive, and many survey organisations cannot attempt the full task of providing contoured maps while they are still facing a tremendous programme of initial mapping.

To what extent are contours required in topographical maps of the scale of 1:50,000 and less? The requirement for contours in military maps for artillery purposes during the last half-century has become so well-established that the need for contours in topographical maps for civil purposes may have been taken for granted—a need which may not be justified in the *initial* mapping of the undeveloped and hilly regions of the world.

In the commission of 1854 under Lord Ellesmere which considered the introduction of contours into the Ordnance Survey one-inch-to-one-mile map, the very distinguished gathering of professional men assembled as witnesses was by no means unanimous on the need for contours in topographical maps. The commission in its findings—"had in view hill-sketching on the ground and hilldrawing on artistic principles to which they proposed should be added selected contours". Contours were not introduced as a complete answer to the depiction of relief but "as an admirable basis for hill-sketching". Some of the engineers amongst the witnesses assumed that they could obtain all the *preliminary* information required for development purposes from a hill-sketched map, and considered that before an engineering project was undertaken larger plans with levelled heights would always be necessary even if a contoured topographical map were available. They therefore questioned the need for spending money on contouring topographical maps of hilly undeveloped country with the consequent delay in the production of those maps. They were content with hillshading allied with spot heights.

Do not the views of those engineers have some application in the modern problem of producing topographical maps of undeveloped hilly areas as quickly as possible? Might not a hillshaded map with spot heights suffice for any preliminary engineering, geological or agricultural reconnaissance, and might it not be as satisfactory for most purposes as a contoured map at the one-inch-to-one-mile scale? Before any project is undertaken, a special survey at a larger scale and with levelled heights or closer contours will surely be necessary? It is realised that the contoured map is used by the modern geologist for the preparation of geological sections and by the modern engineer for the calculation of earth quantities, but is the value of such work, when derived from contours at intervals of 50 feet or more and drawn on maps of the scale of one-inch-to-one-mile or less, enough to justify transferring so much surveying and mapping effort from planimetric mapping elsewhere? A hundred years ago many eminent geologists and engineers were satisfied with hill-sketched maps for the preliminary work on a project. Quite apart from the geologists and the engineers, there are many other classes of map users who will be equally satisfied today.

It is therefore suggested that hillshaded but uncontoured maps may fulfil the initial requirement for topographical maps in hilly undeveloped areas. And being more cheaply and more quickly produced than

contoured maps, they are particularly worthy of consideration because many survey organisations which cannot undertake the full task of contouring may be able to consider the less expensive programme of hillshading. But it must be appreciated that just as contours need to be accurate to be of value, so hillshading must be well done to satisfy the map user.

Mr Robert Dawson, as long ago as 1854, in a letter to Lord Ellesmere's commission, wrote :— "By a Topographical map then I should understand a full face pictural representation of a place, district, or country, in its natural figuration of mountain, hill, valley and plain.... the whole united harmoniously in one pictural exhibition to the eye.... It is natural history drawing of land in full perspective perception". It is a definition which every cartographer should at least appreciate if not adopt. It is a definition which has influenced the author of this paper to put forward the above suggestion for hillshaded but uncontoured topographical maps in undeveloped mountainous areas where mapping resources are limited.

[1] For a brief historical summary see : L. J. Harris, O.B.E., Hillshading for Relief Depiction in Topographical Maps. *Journ., Roy., Inst., Chartered Surveyors*, March, 1959.

[2] Puissant, L. *Traité de Topographie d'arpentage et de nivellement*, 1820.

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THE INTERNATIONAL CONGRESS OF PHOTOGRAMMETRY

A major event in the cartographic world in 1960 will be the quadrennial Congress of the International Society of Photogrammetry to be held at London University from the 5th to 17th of September. A full programme of technical papers and discussions has been arranged under the seven Technical Commissions of the Society which deal with Photography, Plotting Theory and Instruments, Aerial Triangulation, Mapping from Photographs and other branches of the subject. Of particular interest to geographers will be the work of Commission VII, devoted to photo-interpretation and including working-groups on "Interpretation of Surface Configuration", "Drainage", "Soils", "Geology", "Interpretation of Vegetation", "Interpretation of Urban, Rural and Industrial Features", and the "Interpretation of Ice Features.

This will be the first occasion that the International Society, to which the national societies of thirty countries adhere, has held its Congress in the United Kingdom. Previous post-war congresses have been held at the Hague (1948), Washington (1952) and Stockholm (1956). H.M. Government have officially recognised the holding of the Congress which is under the patronage of the Duke of Edinburgh and is organised by the joint hosts, the Photogrammetric Society and the Royal Institute of Chartered Surveyors.

A preliminary programme and application forms for preliminary registration can be obtained from the Congress Director, 18 Cavendish Square, London, W.1.

A BOG-BURST IN THE ISLE OF LEWIS

D. R. BOWES

The national daily papers, published on the 1st of December 1959, contained reports of a small loch — Loch nam Learga — between Morsgail Lodge and Kinlochresort, some twenty miles west-south-west of Stornoway (Nat. Grid 19/128193) that had been found drained on the 20th of November. Deep gullies in the peat below the outlet of the loch and a swollen, muddy stream issuing from a lower loch — Loch Mor Shéilabridh — were also reported. It was suggested that these phenomena may have been caused by a meteorite. To investigate these reports, the author was flown to the spot and examined the area from the air and on the ground.

From the air, an elongated dark-brown scar stood out in marked contrast to the surrounding moorland which was largely covered with light-coloured grass, except for rounded knobs of bedrock and small lochs (Plate 2). The drained loch was situated on a relatively high, but flat part of the moor (approximately 340 feet O.D.) with its outlet near a break of slope, the slope leading southwards down to the lower loch (approximately 310 feet O.D.). The appearance was that of a breached dam with the following parts (Plate 3) : —

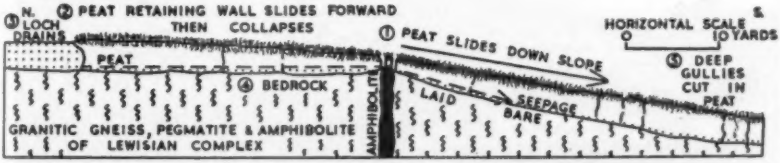

Fig. 1. Cross-section of the area immediately south of the drained loch, showing the sequence of events during the bog-burst.

(1) the upper, drained loch, stretching north-south, with dark-brown peat sludge at the bottom; a retaining peat-wall at the southern end, breached and with large dislodged peat blocks strewn about; (2) an area of bedrock cleared of its peat cover and much of it having a gentle southerly slope; (3) a network of deep channels and gullies in the peat between the two lochs with bedrock showing in parts and some large boulders in the channelways; (4) the lower loch, stretching east-west, with a large outwash alluvial fan spreading out from the main channelway which represents the stream that joined the two lochs prior to the wash-away.

On the ground the drained loch was seen to be nearly two hundred and twenty yards long and sixty yards across. Much of its floor was covered with a layer of peat sludge on bedrock, but fibrous peat, much cracked by recent exposure to air was present, particularly at the eastern side (Plate 2). This peat contained many scoured potholes. The floor of the loch at the northern end was strewn with boulders up to a foot across, in between which were patches of peat and sand, the latter showing ripple marks. The loch had been approximately four feet deep at

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CAPTIONS FOR PLATES 2 AND 3

(Centre-spread)

PLATE 2. Aerial photograph from 800 feet looking north-north-west over Morsgail Moor and showing the area of the bog-burst with drained Loch nam Learga at centre right and the eastern end of Loch Mor Shéilabridh, with the outwash alluvial fan, at bottom left.

PLATE 3. Aerial photograph from 800 feet looking south-west over the area affected by the bog-burst. Drained Loch nam Learga is at bottom right, with the breached retaining-wall, large dislodged peat-blocks and the subsidiary washout at its southern end. Immediately to the south of this is exposed bedrock, the channelled and gullied area, and the outwash alluvial fan in Loch Mor Shéilabridh.

the margins and six feet deep at the centre and had been held by a peat retaining wall six feet high (Fig. 1). The top foot of peat was bound by the root system of mat grass (mainly) but the remainder was amorphous peat which was saturated with water at its junction with the bedrock. This peat retaining-wall which had been breached at the loch outlet with a gap of eight feet across (between large dislodged blocks — see Plate 2) and six feet deep, rested for thirty yards upon an almost flat, glacially polished surface of hard, impervious, little-jointed Lewisian gneiss. At the change of slope leading to the lower loch, and corresponding with the line of change of slope across the countryside is a ridge of greenish-black amphibolite which had been left protruding because of its differential erosion with respect to the dominant microcline-bearing granitic gneiss. Above this rib, the peat was seen in the east bank to be less than two feet thick (Fig. 2) with the top-half bound by the grass root system. To the south, the surface of the bedrock slopes

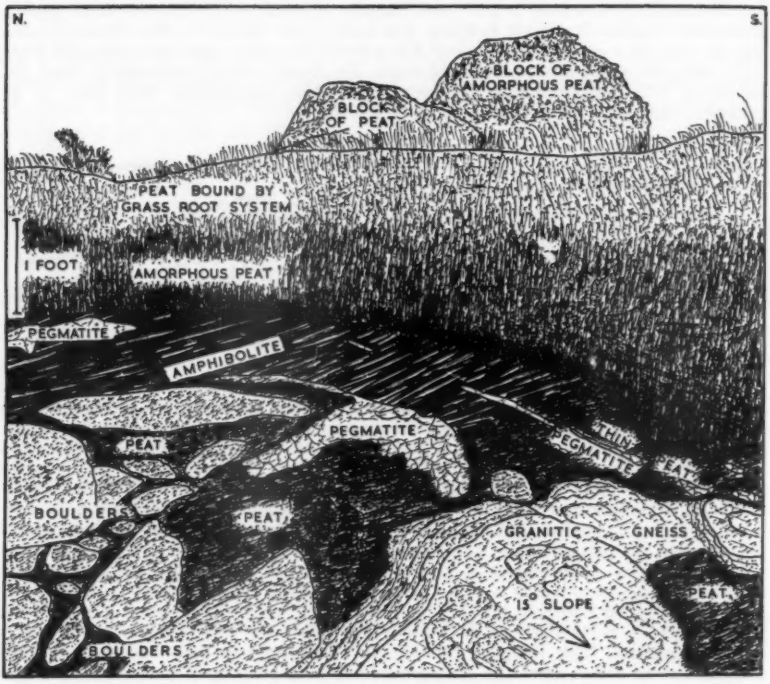


Fig. 2. The vertical east-bank of the washout thirty yards south of the drained loch and the bedrock exposures on the washout floor.

away at about 15 degrees — this slope almost corresponding with the foliation of the granitic gneiss — although the surface slope of the peat is much more gentle (see Fig. 1). Much of the area between the breached dam and the rib had been denuded of its peat cover, while there was almost complete rock exposure for thirty yards of the slope over a width of thirty yards, below the amphibolite. In the deeply channelled area between the bare bedrock and the lower loch — approximately one hundred and seventy five yards by ninety yards — the peat was between five and six feet thick and very much cracked, with deep narrow clefts between adjacent masses. Many large peat-blocks had slid away from the walls of the channels; some were still upright, but others had not only slid, but had tilted and tumbled. The alluvial fan in the lower loch was one hundred and fifty yards long and seventy yards across and was itself channelled in parts making

it appear like a delta. It was built up largely of amorphous peat-sludge and blocks of fibrous peat.

There were many causes contributing to this bog-burst. The early part of the summer in the Isle of Lewis was very much drier than normal and this aided the drying out and cracking of the peat, particularly over the amphibolite rib where the peat was thin. By contrast the rainfall in late October and November was considerable and almost continuous (rainfall was recorded at Stornoway on each of the thirty-five days prior to the 20th of November giving a total of 26.2 cm). The bedrock of Lewisian gneiss is hard and impervious and glacial erosion has left a change of slope at the amphibolite rib close to where the growth of peat later dammed back the upper loch. Here, the surface of the bedrock was almost flat and hence the strength of the peat retaining-wal was dependent largely on the support given by the continuous mass of peat from the dam down to the lower loch.

During the period of heavy and almost continuous rain prior to the burst, much water must have soaked down through the peat, particularly using the contraction cracks as channelways, and added to the water which had seeped from the loch along the junction between the peat and the bedrock (see Fig. 1). The amorphous peat became saturated with water and at this peat-bedrock junction, instead of seeping, it gradually began to flow. This seepage undermined the peat and enabled the mass resting on the bedrock, with a slope of 15 degrees, to slide down the slope under the force of gravity (water and saturated peat acting as lubricants), breaking away from the rest of the peat over the amphibolite rib where it was thin and well-cracked and closing the contraction cracks in the peat lower down the slope as it moved forward (see Fig. 1). This left the thirty-yard-wide peat retaining-wall which was resting on a relatively thick amount of saturated peat and water dammed up behind the protruding amphibolite bar, without the support of the continuous mass of peat from the bar to the lower loch. The weight of water in the swollen loch (of the order of 10,000 tons) then gradually slid the peat retaining-wall forward over the bedrock until the wall gave way. The water flooded free — under the sliding blocks, around them and over them in turbulent flow. As the peat blocks were tumbled forward, blocks of peat were broken off and carried by the turbulent water which rushed over the surrounding banks, depositing blocks of peat on these banks (Fig. 2), in some cases above the original level of the loch. With the retaining wall breached, a small subsidiary washout occurred just to the east of the loch outlet (Plate 2). The force of the escaping water scoured some of the bedrock free of its cover of peat, particularly just below the amphibolite bar, channelled and gullied out a large area and washed the debris out into the lower loch. The water in this loch would then become brown due to suspended peat and the stream emptying it brown and swollen as had been reported.

Grateful acknowledgement is made to the *Scottish Daily Express* for flying the writer to the site, and for permitting the reproduction of the photographs.

JOHN AINSLIE'S MAP OF PORT GLASGOW IN 1806

IAN A. G. KINNIBURGH

Port Glasgow must have been a pretty sight at the beginning of the nineteenth century, as can be seen from Ainslie's map (Pl. 1). Round the Bay of Newark there was a little group of neat white houses overlooked on the east by the castle of Newark (c.1450) and on the west by the harbour, no doubt, in 1806, crowded with ships and bustling with trade. Around the single-storey white houses the level, sandy raised beach—early to warm up in the spring sunshine—supported orchards and vegetable gardens. This level strip was very narrow, being in places only 130 yards wide, and was backed by the fault-riven edge of the hard basaltic plateau-lavas. Later, this narrow site was to restrict the town's growth but, at the time of the map, the town covered quite a small area.

The original area of Glasgow's "Newport", was a mere 14 acres, bought from the laird of Newark in 1668 to enable the city to advance her trade from an outport of her own beside the deep water of the Firth of Clyde. Trade was thriving by 1806. Ainslie's map shows evidence of this activity in the town's harbour for a scheme to develop the port can be seen drawn on Ainslie's plan. It will be noticed that this scheme included a new dry-dock to increase the facilities offered by the existing dry-dock which had been built immediately to the east of the harbour in 1763 and was the oldest in Scotland. Reference to Figure 1 will show that this proposed new harbour was, in fact, not built. Later, in 1836, however, a new wet-dock was built in the Bay of Newark. This scheme, simpler than that shown on the map of 1806, had first been proposed in 1772 but only after 1830 was it initiated. This new dock, which had a depth of 25 feet, was to ensure that Port Glasgow should maintain its position of a major port on the Clyde despite competition from Greenock and Glasgow, both of which had become independent ports, free from the jurisdiction of Port Glasgow, by

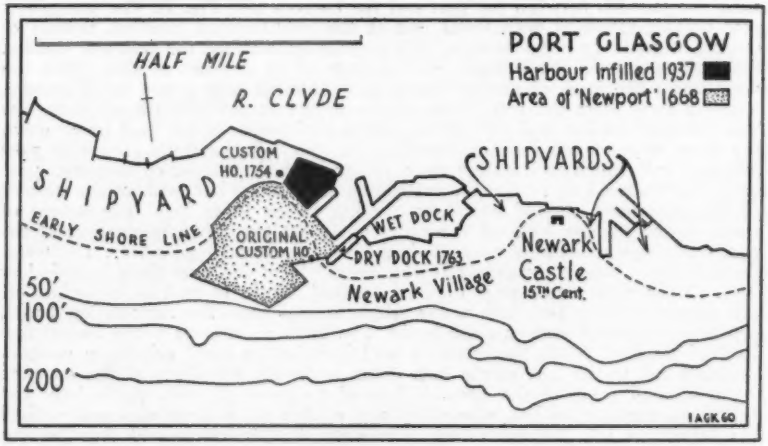
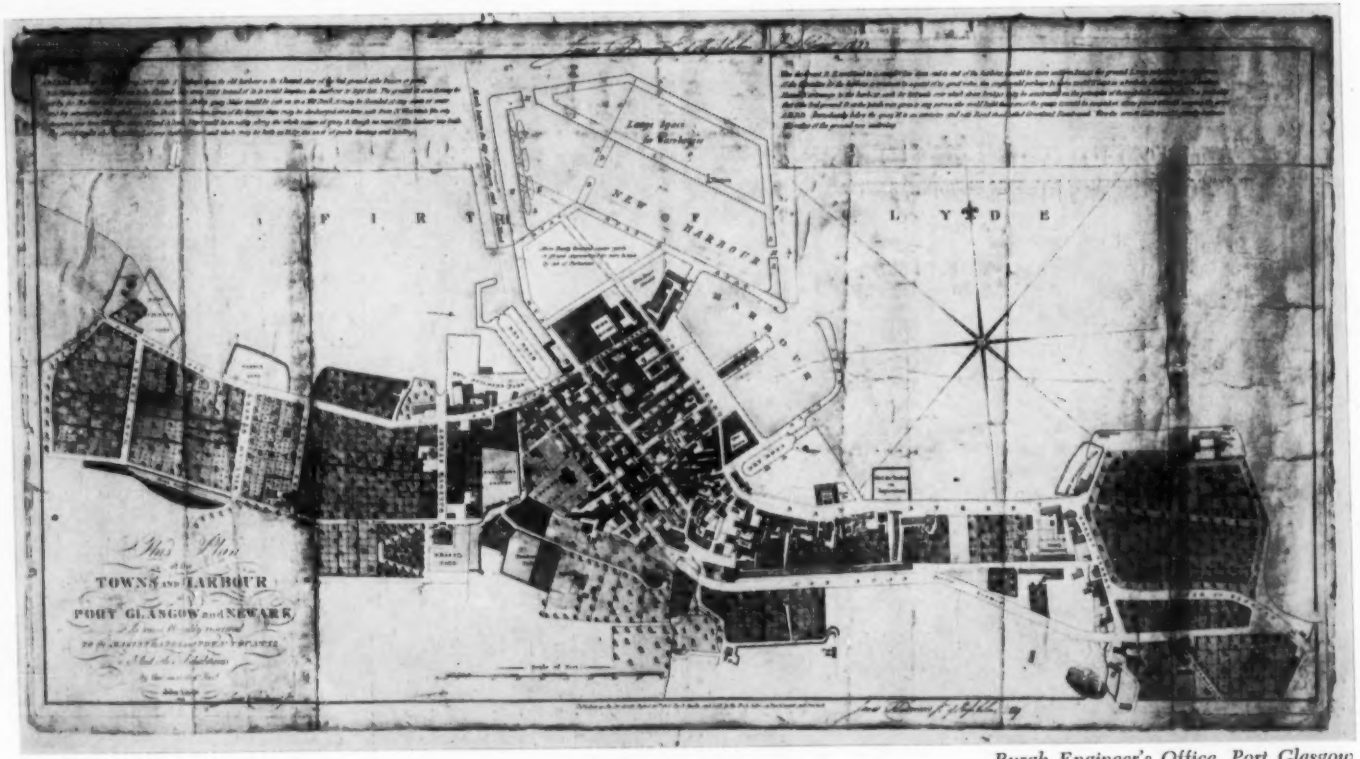


Fig. 1. Port Glasgow: harbour development.

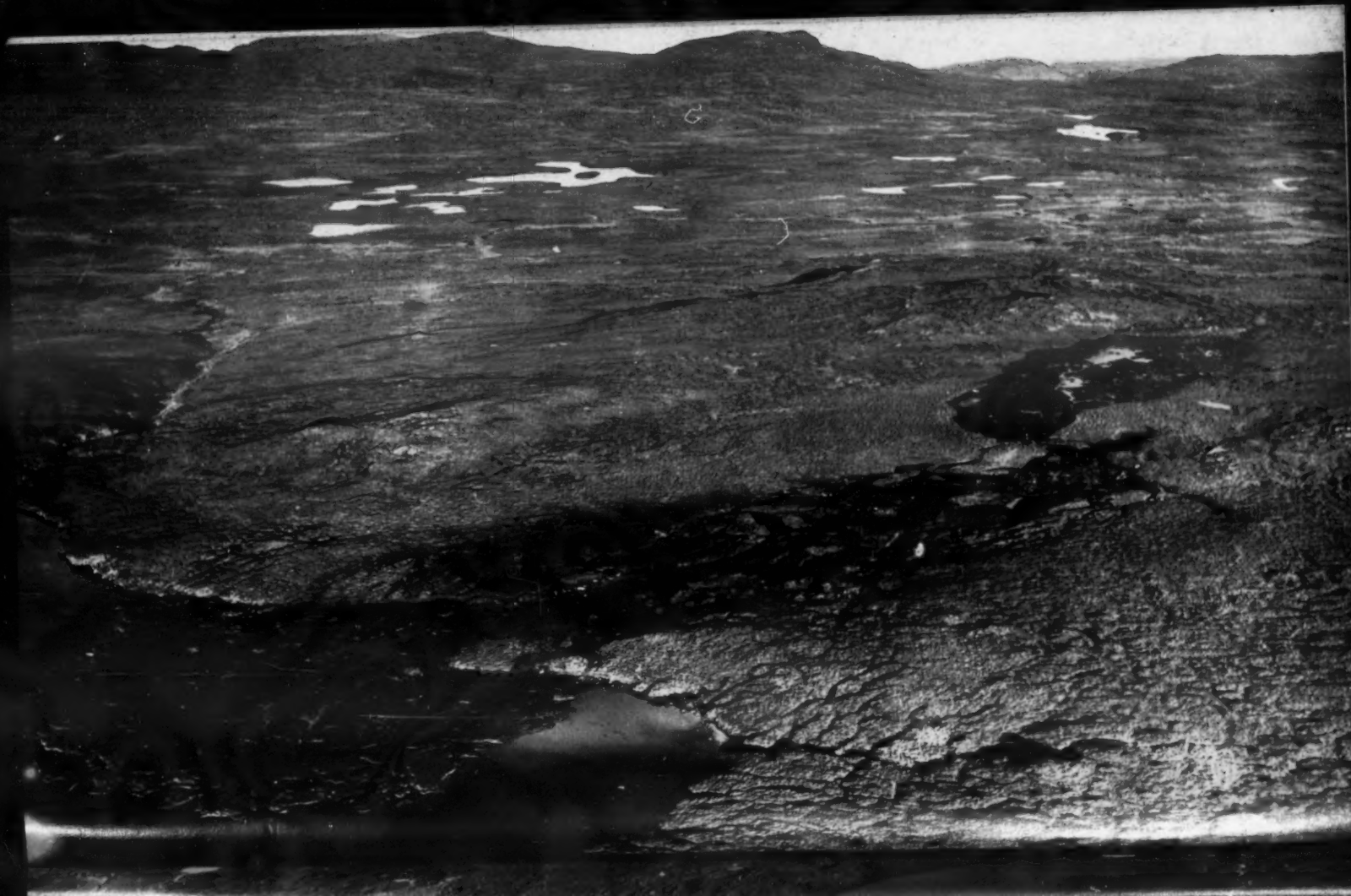
1812. The Clyde was now deep enough to take ships of all but the largest size up to Glasgow, and Port Glasgow was in danger of losing her trade. In fact trade did decline and the new harbour was too late to prevent this for in 1839 the gates of the wet-dock collapsed. The coming of the railway in 1840 also deprived the port of much trade and in 1845 the last cotton cargo was discharged in the harbour. Latterly the only commodity of note being imported was timber, from North America, and this traffic too began to die when iron and, later, steel ships replaced wooden vessels. Trading virtually ceased by the middle of the nineteenth century. From then onwards the harbour has been used chiefly for the fitting-out of small coasting vessels.

To-day the harbour, once the chief on the river, stands derelict and one part of the original harbour has been filled in (1937) to form a park. This provides a much needed open space in a town where space is limited and much of the town's area is on ground having an average gradient of 1 : 5. It may be that the other harbours will be filled up in the next few years. The Development Plan for the town envisages the reclaiming of the space now used by the harbour so that an industrial estate can be formed and the main road (A8) re-aligned. Glasgow's c ;port has had a useful life of 300 years but its port function has gone a .t the town now looks to shipbuilding for a livelihood. Perhaps it is significant that the plan for the future is to replace the harbour with an industrial estate to bring new work to the old port.



Burgh Engineer's Office, Port Glasgow

Pl. 1. Ainslie's Map of Port Glasgow, 1806.
(Scale : 150 feet to one inch; Size of printed area 35 × 17.5 inches)



Royal Scottish Museum

Pl. 4. Hispano-Moorish Astrolabe of Muhammad b. as-Saffâr.
(bronze; 155 mm diametre)

DISCOVERY OF AN OLD ASTROLABE

ROBERT W. PLENDERLEITH

The astrolabe is a rare instrument. Although its history can be traced back through sixteen hundred years, only some eight hundred examples are known to have survived and collections including more than one or two of these fascinating instruments are few.

In the Science Gallery of the Royal Scottish Museum thirteen astrolabes are displayed. This large collection includes examples from Persia, India, Arabia, Spain, Germany, France and Holland with dates ranging from the fourteenth to the eighteenth century. Here, in the same display case, the masterpieces of craftsmen of many lands and of different ages meet and can be examined and compared. For, while the mathematical construction of the astrolabe remained unchanged throughout the ages, no scientific instrument has been the basis for greater variety in artistic embellishment. In fact, it is by the artistic treatment of its features that the source of an astrolabe can usually be quickly determined.

To this representative collection there has recently been added an astrolabe of outstanding interest. It was found some years ago in an antique dealer's shop in Edinburgh and purchased by Mr James H. Farr, an Edinburgh motor engineer, well-known as one who takes a special interest in the preservation of examples of craftsmanship of earlier days. Some months ago the instrument was brought to the museum for examination when it was immediately seen to be similar to the oldest Islamic astrolabes known, tenth-century examples of the skill of the Arabian craftsmen. The tracery of the front plate, or *ankabut*, with its severe dagger-shaped star-pointers marking the position of the principal stars in stereographic projection, suggested that the instrument might have come from the hands of a Syrian craftsman, but not until its engraved inscriptions were understood could this be verified. All the inscriptions are in Kufic, an early form of Arabic script which presents considerable translation difficulties. The astrolabe was photographed and prints were sent to the History of Science Museum at Oxford where, after careful study, the Kufic yielded its secrets to the expert. The result was surprising as it was discovered that the astrolabe was made in Spain. An inscription on the back, when translated into English, read : — "*Work of Muhammad b. as-Saffâr in Cordova in the year seventeen and four hundred*". Islamic centuries being reckoned from the year of the flight of the prophet Mahomet, the date of the instrument could thus be accurately determined as 1026/27 A.D., proving it to be the oldest-surviving, dated astrolable from the *Maghrib*, or Arabian "land of the West", and one of the ten oldest astrolabes in the world. On discovering its historical importance, Mr Farr very generously presented the astrolabe to the national collection in Scotland.

Spain, at the end of the tenth century, was under Moorish influence with Cordova as the intellectual centre. Here, history records that during the reign of the Umayyad Caliph of Cordova, al-Hakam II (961-976), the study of science, mathematics and philosophy flourished and, stimulated by the formation of a large library of scientific books imported from Baghdad and Cairo, encouragement was given to the public appreciation of the sciences. The explanation of the similarity to the Syrian instruments was now clear. Several later astrolabes from the craftsmen of Moorish Spain are known and recognised by rich ornamentation in characteristic form; but the masterpiece of Muhammad b. as-Saffâr pre-dated the *Maghribi* tradition and, being based on knowledge directly derived from astronomical work in Syria, featured characteristics of the Syrian instruments. Another astrolabe by Muhammad b. as-Saffâr.— the name Ibn as-Saffâr means the "son of the coppersmith" — is known to hang in the Westdeutsche Bibliothek at Marburg in West Germany. It is dated 1029/30 A.D. and was made in Toledo.

The instrument now on exhibition in the Royal Scottish Museum and shown in the adjacent illustration, has seven double-sided latitude plates giving fourteen projections for use at various latitudes. These plates are inscribed with the names of cities as far apart as Constantinople and Qulzum, the site of which is near to the present town of Suez, and there is also an unusual projection for an observer on the equator. One of the plates can be seen immediately below the fretted *ankabut*, and shows the *almucanters*, or circles of zenith distance, from which star positions can be determined from the star-pointers, provided the *ankabut* is rotated to its correct position according to the hour of the day or night.

THE ORIGIN OF LOCH LOMOND

D. L. Linton and H. A. Moisley.

"Loch Lomond is unquestionably the pride of our lakes ; incomparable in its beauty as in its dimensions, exceeding all others in variety as it does in extent and splendour, and uniting in itself every style of scenery....."

John MacCulloch *The Highlands and Western Islands of Scotland,* 1824 Vol. 1, p.209.

MacCulloch's eulogy has often been repeated and with some justification. Loch Lomond is the largest of Scottish lochs ; its area of 27.45 square miles exceeds that of its nearest rival, Loch Ness, by nearly six square miles. In terms of length, at 22.64 miles along its axis, it is exceeded only by Loch Awe (25.47 miles) and Loch Ness. The maximum depth, 623 feet, makes it the third deepest in Britain, only Loch Morar (1,017 feet), and Loch Ness (754 feet), being deeper. As such, and perhaps because it lies so close to the greatest city and most densely populated part of Scotland, Loch Lomond has long been accepted as a major feature of Scottish scenery. As early as 1872 it attracted the attention of Kinahan [1], who assumed that it was essentially of tectonic origin though in the light of Juke's then recently published work on the rivers of southern Ireland [2], he allowed that "marine action, meteoric abrasion and ice, separately and combined, performed their respective parts...." [3]. Some of the dislocations he added, "are post-glacial" and in this way he sought to explain the contrast between the deep northern troughs and the shallow southern basin. His view was, however, opposed by James Geikie in 1894 who stated categorically "it does not lie in a line of dislocation or gaping fissure, still less does it owe its origin to an unequal movement of elevation or depression, or to rock flexure. It is as excellent a specimen of an excavated basin as any glacialist could desire" [4].

The contrast of the upper and lower portions has long been remarked ; indeed it is the combination of lowland and highland scenery that makes Loch Lomond peculiarly attractive to the tourist even today. In their description for the report of the Bathymetrical Survey in 1910[5], Peach and Horne described the upper or Highland and lower or Lowland sections, and, following James Geikie regarded it is a typical valley rock-basin "lying across the strike of the strata in a valley in great part excavated by one of the original consequent streams of Scotland draining towards the south-east". They and later writers, have described the upper lake as a narrow glacial trough, incised into the Dalradian schists and related rocks of the highland plateau. The lower lake was regarded as a lowland lake, comparable with the Lake of Menteith and Loch Leven (Kinross) or with the piedmont expansion of such a lake as Lake Garda. In fact the widening begins well north of the Highland Boundary Fault, in the outcrop of the Ben Ledi grits and Luss Slates, although the former do provide something of a barrier in the lake floor, represented for example, by the islands of Inchlonaig, Inchtavannach and Inchconnachan.

At the time of the Glasgow British Association Meeting in 1928 Gregory returned to the subject [6], again commenting on the contrast in "geographical character" between the two sections and explaining it in geological terms. But, in addition, he drew attention to the obvious youth of the valley, as compared with the older, west-north-west to east-south-east valleys. He discarded the glacial erosion theory and returned largely to Kinahan's tectonic thesis. "The Loch Lomond basin may therefore be regarded as a tectonic depression due to the Pliocene uplift of Scotland, during which.... the floor of the loch sank along a main north and south fault...." [7]. He saw in the spectacular and almost unbroken eastern wall of the valley the fresh scarp of such a recent fault. Gregory's observations were remarkably acute; he certainly saw the need for a fuller explanation of the valley than had hitherto been given; but, as was natural to the author of *The Nature and Origin of Fiords*, the tectonic explanation obsessed him and, like his predecessors, he overlooked some essential facts about the valley which, once perceived, make the question of its origin a problem of the first magnitude. It is perhaps appropriate that, on the occasion of the return of the British Association to Glasgow in 1958, the writers had the opportunity of observing and discussing with visiting colleagues these essential, and often anomalous facts. The present paper is a record of these observations and they are set out, together with some tentative conclusions, in the hope of stimulating further discussion of a too long neglected topic.

Firstly, it is remarkable, and contrary to the rule enunciated by James Geikie in 1894 [8], that the largest of Scottish lochs should, (apart from the anomalous Endrick-Blane drainage which is essentially a Lowland drainage directed to a Highland lake) drain only an area of about 160 square miles. The limits of its basin (Fig. 1) often lie very close to the Loch, and, along much of its eastern side, immediately overlook its shore; it was the unbreached nature of the eastern valley wall which was claimed by Gregory as evidence of recent faulting. Indeed the only substantial east-side tributary is from Loch Arklet (draining an area of about ten square miles) the tributaries of which have a pronounced eastward tendency towards Strath Gartney. Their diversion to Loch Lomond is clearly very recent and the descent at Inversnaid is a steep post-glacial gorge of adjustment. Similarly at the head of the Loch, Gleann nan Caorunn and Glen Falloch form a limited tributary area of about forty square miles, wide open north-eastwards to Glen Dochart and used as a pass by road and rail. The drainage of this area is poorly articulated with Loch Lomond. West of the Loch catchment consists of (i) a small area about ten square miles centred on Inveruglas (Loch Sloy power station) and ringed round by very high peaks, and (ii) an area of about sixty square miles, drained by Glen Douglas, Glen Luss, Glen Finlas and Glen Fruin which were recognised by Cadell as being part of the earliest drainage of the area [9] a view accepted by Gregory in his paper on Loch Long [10] and more recently by Bremner [11], and one from which we see no reason to dissent.

In the sequel we shall suggest that, preglacially, Glen Dochart in the north and the Glen Douglas - Glen Fruin group in the south were parts of drainage systems that were then quite independent and that

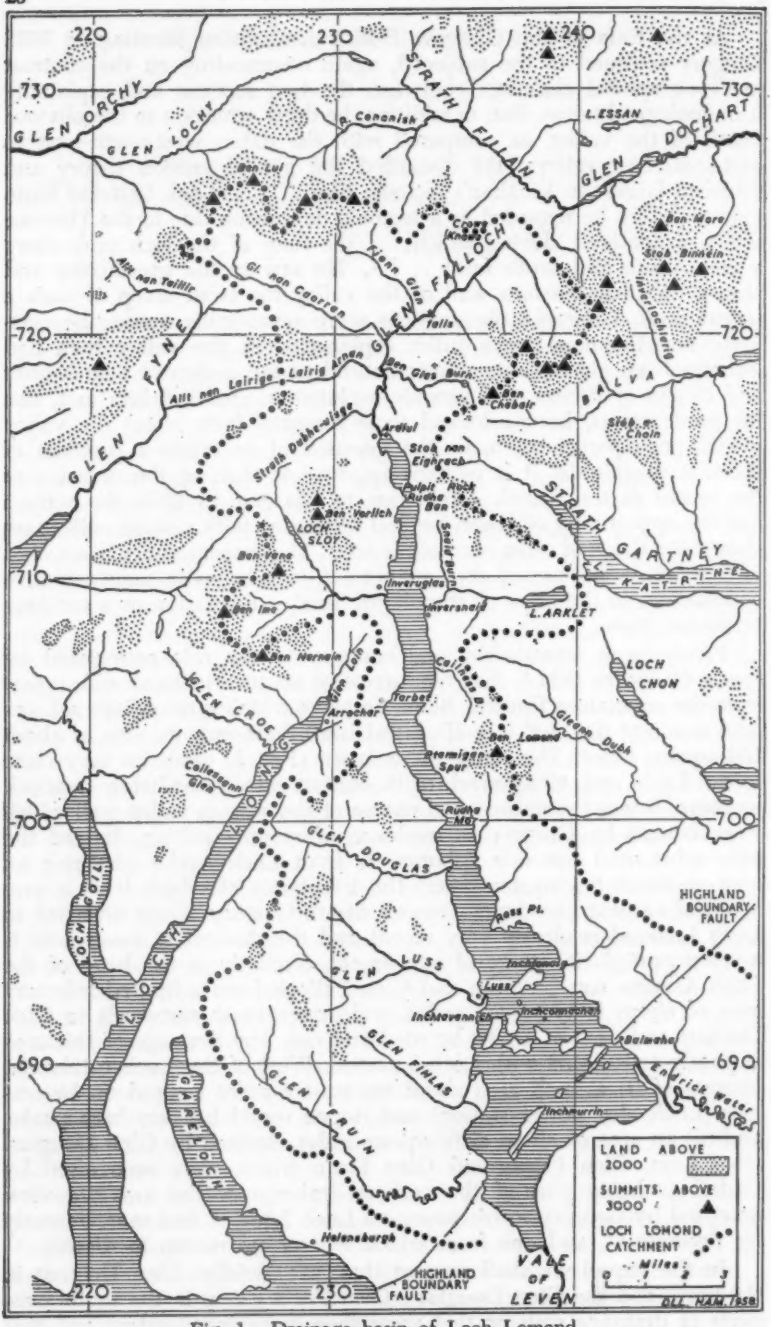


Fig. 1. Drainage basin of Loch Lomond.

Loch Arklet drained away to the east, having its headwaters in what is now the Inveruglas basin, as suggested by Peach and Horne [12] and accepted by Bremner.

Secondly, there can be no question that, as noted by Archibald Geikie in 1901 [13], Loch Lomond is transverse to geological structure: stratigraphically it traverses a variety of Dalradian strata including the Ben Ledi and Leny grits and less resistant mica schists, the Highland Border Series and the Old Red Sandstone; tectonically its general line seldom, if ever, corresponds with any of the well-established fault systems of the region. Indeed, its very irregularity distinguishes it from those Lochs like Ericht, Laidon and middle Tay, which occupy subsequent valleys etched out along fault lines. This statement is quite contrary to Gregory's expressed view but modern geological research [14] shows no reason to suspect the existence of a recent major fault, completely hidden by the loch, yet not disturbing the rocks to the north and south, such as his thesis required.

It would therefore appear at first sight that the line of Loch Lomond must be that of an early valley, superimposed across these varied structures from some level high above the present Highland summits. The clearest contradiction of this lies in the minuteness of the present Loch Lomond drainage basin, particularly if we allow for the anomalous sectors described above. An alternative possibility exists. The valley may be of composite origin, made up of bits and pieces of earlier drainage systems integrated by the agency of glacial erosion. Cadell's and Bremner's reconstructions [15], [16] of the early drainage systems of the region require some integration to explain the Lomond valley, which cuts across three of their early river systems.

If Loch Lomond is inspected from the slopes of Rudha Mor, opposite Ben Lomond, it is at once apparent that there is here a critical point in the valley. To the south the Loch is up to five miles broad with open, flaring sides, shallow and broken by islands. To the north it seldom even approaches a mile in width and for eight miles is more than 400 feet deep; moreover the sides are steep and, on the eastern side in particular, almost sheer with a sharp discontinuity between the steep slope and the upland plateau (Fig. 2). To the south the island pattern suggests a measure of adjustment to structure which, whilst clearly modified and in places reduced by ice erosion, may have had its origin in preglacial times. The summits of the greywacke islands (Inchlonaig and Inchtavannoch) and the quartzite peninsula of Ross point are "knobbly" and reach 200-300 feet, as do the southern islands (Inchcailloan and Inchmurrin) which have cores of resistant serpentine. These give some indication—at least a minimum—for the general level of the preglacial surfaces in this area. The 400-500 feet summits of the hills just south of the Loch, including the volcanic neck Duncryne may also be adduced. It is most significant that Rudha Mor also marks the northern limit of the only extensive Highland catchment basin draining to Loch Lomond. These contrasts suggest that from Rudha Mor southwards Loch Lomond is the glacially modified and perhaps diverted basin of the Douglas-Fruin drainage, the original outlet of which was possibly south of the Campsies, by Strathblane (at about 500 feet) to the Forth. Other outlets are possible [17], but

seem to us less likely. The diversion of this drainage by the Vale of Leven to the Clyde may have taken place before glaciation intervened. Alternatively, the Fruin and Finlas may have been independent of the Douglas-Luss system as shown in the diagram (Fig. 3) and as suggested by Cadell and Bremner, in which case the Vale of Leven must represent their former continuation, though now greatly modified by ice action. The origin of the Vale of Leven, a deep transverse valley, essentially a continuation of the Lomond valley, is a problem which links the present one with the evolution of the lower and middle Clyde—a problem to which we hope to return.

If our interpretation is correct the northern watershed of the Douglas drainage crossed the Loch from Rudha Mor to Ben Lomond (Fig. 3). On the ground this section of Loch Lomond, and the adjacent slopes, reveal many features displayed elsewhere by glacially breached watersheds (Fig. 2):

(i) The steep, heavily ice-worn but irregular eastern slope, suggests powerful but incomplete ice erosion. The slope is rough-hewn and unfinished compared with some otherwise comparable troughs; but the rock-basin has a floor more than 500 feet below sea level just north of Rudha Mor.

(ii) Rudha Mor is the tip of a substantial promontory, some 500 feet in height and jutting half-a-mile into the Loch. This promontory has every appearance of being the ice-drubbed remnant of the former divide, not completely removed.

(iii) A mile north-east of Rudha Mor is the Ptarmigan spur (2,396 feet) of Ben Lomond. From it descend high-level valleys to north and south, relatively little modified by ice and suggesting preglacial valleys; on the north Cailness Burn is graded to a level about or just above 1,000 feet, on the south the grading is perhaps to a level a little lower. Both now have outlets to Loch Lomond which hang many hundreds of feet above the glacial trough. The upland dissected by these and other streams, appears to be one of mature dissection with a range of relief from 1,000 - 2,000 feet O.D. above which Ben Lomond rises as a monadnock. The eastern slope of the Lomond trough intersects this upland as if it had been cut through it with a knife (see Fig. 2).

(iv) The western slope, north of Rudha Mor, on the other hand, is ice-eroded to its summits (2,000 - 2,200 feet) and there is little evidence here of preglacial drainage except that the Douglas system did not extend beyond them.

These considerations are strongly reinforced by an examination of the relation of the present upper Loch to the other drainage lines of the area.

In any view from the summits of Ben Ime, Ben Vane or the southern spurs of Ben Vorlich nothing is more impressive than the apparent continuity of the valley that runs east from Ben Ime to Inveruglas with the through valley that holds Loch Arklet and Strath Gartney beyond. Such an interpretation implies that Loch Lomond is an interruption of the continuity of this system, and both the character of the Loch Lomond trough and the absence of any favouring structures that would guide or facilitate river capture suggest that the beheading of any former Arklet-Strath Gartney stream has been effected by glacial invasion of its upper drainage basin. Such invasion would be by ice from the north, overriding a col in the general line of 3,000-foot mountains that runs by Ben Ime and Ben Vorlich to Ben Chabhair and Ben More, and converting such a col into a breached watershed. The observed details in the field are entirely in accord with this view. At the Pulpit Rock and Rudha Ban, one-and-a-half miles from the head of the Loch, the lake narrows to a mere 400 yards and is bordered on both sides by heavily ice-scoured spurs with roches moutonnées.

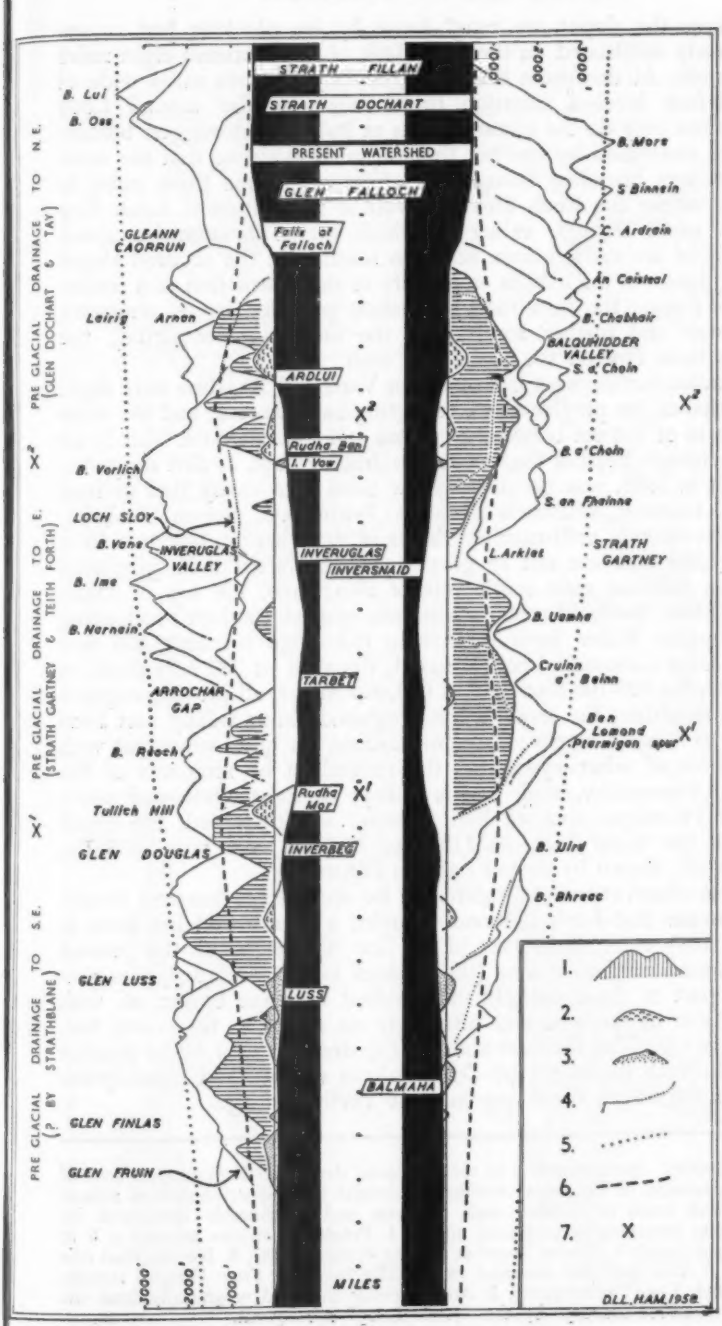


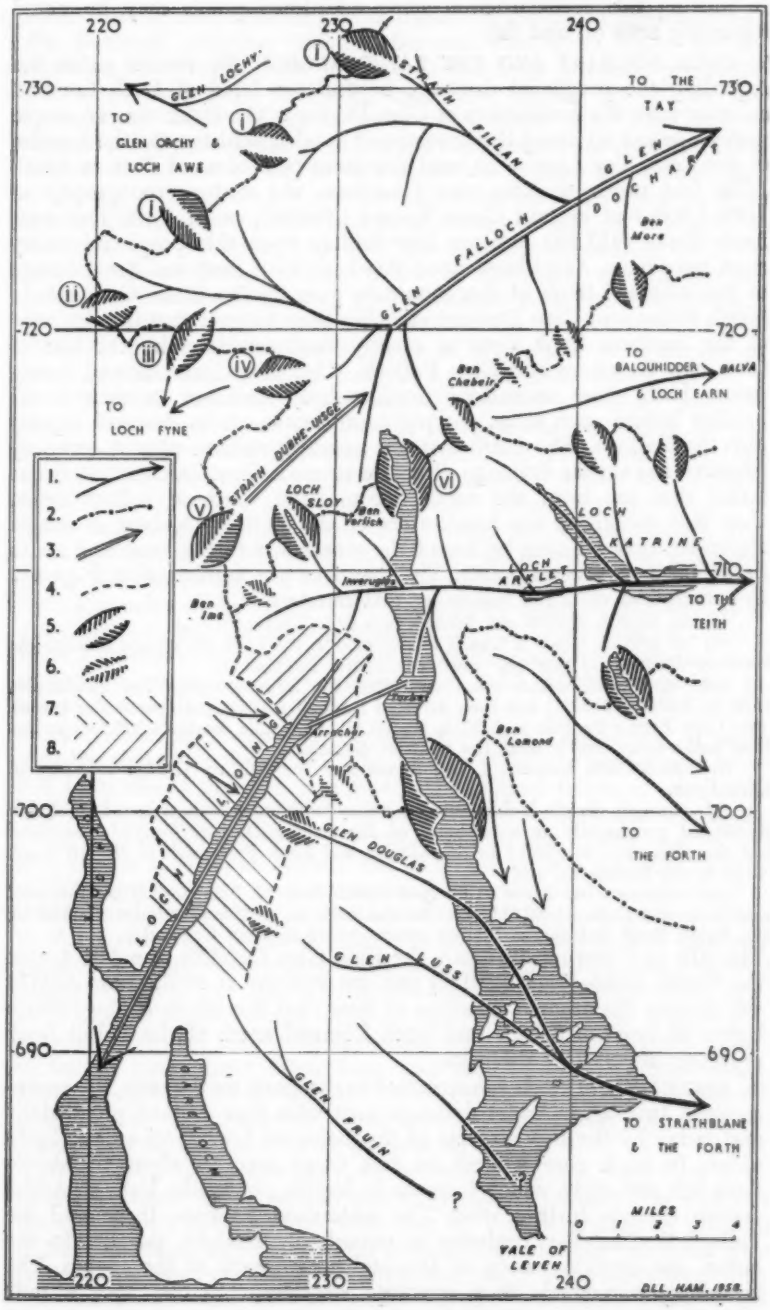
Fig. 2. Projection of Loch Lomond trough and adjoining country to west and east on to grid line 235,000 : 1. Outlines of severely over-steepened sections of eastern wall of trough and of truncated spurs west of Loch Lomond; 2. Ice-moulded projections into basin; 3. Islands rising from trough floor; 4. Profiles of certain streams which may represent modified portions of preglacial drainage; 5. Conjectured level of ice surface at late stage; 6. Inferred form of preglacial valleys and divides, approx. along line of present trough; 7. Site of major preglacial divides ; $\times^1$ South of Glen Dochart - Tay drainage; $\times^2$ South of Arklet - Katrine - Teith - Forth drainage. Section of trough along line of maximum depth, or lowest altitude; vertical distance between it and 5 represents conjectured thickness of ice at a late stage in evolution of trough ,and between it and 6 represents probable thickness of rock eroded along trough.

Above these the slopes are rough-hewn by ice plucking just as are those already mentioned on the west flank of Ben Lomond eight miles further south. At this point the trough is only just two miles wide at the 2,000-foot level—a situation found nowhere else around Loch Lomond. Not only do the circumstances at Pulpit Rock suggest breaching of the watershed by ice, but there is good evidence that the same watershed was breached though less effectively, some three miles to the west, where the Loch Sloy reservoir is now situated. Loch Sloy lies in a small through valley in which roches moutonnées speak eloquently of ice motion from north to south. But the scoured slopes are rough hewn in the middle and testify to the destruction of a former watershed: upon the firm rock foundation provided by its remnants, much lower and further south than the original waterparting, the engineers have erected the Loch Sloy dam.

Two miles further west between Ben Vane and Ben Ime only slight modification of the preglacial water-parting has occurred, and the same may be said of the col between Ben Ime and Ben Narnain. This latter forms the former head of the Inveruglas drainage but, as first suggested by Cadell in 1886, was preglacially the head of a valley that drained to Strath Gartney, Callander and the Teith-Forth system. Probably the present smooth, drift-mantled slopes of this glen grading to a floor at 1,000-1,200 feet are not so greatly different from their preglacial form. The 950-foot spur south-west of Ben Vane, the top of Dubh Cnoc, 945 feet, the bold roche moutonnée spur at 900 feet overlooking the Inveruglas Water from the north, the ridge reaching 833 feet between Glen Loin and Loch Lomond, the spur at 763 feet north of Inversnaid, the 600-700-foot lip east of Loch Arklet, all provide suggestive hints regarding the level of the preglacial valley falling east from Ben Ime to Strath Gartney. These indications are quite consistent with the altitudes of what appear on the ground to be remnants of the preglacial topography, such as the valleys draining north and south from the Ptarmigan spur of Ben Lomond already noted, the upper reaches of the Snaid Burn (345115), and the Ben Glas burn (335175), further north, shown by dotted lines on Figure 2.

If these observations and inferences be accepted it becomes necessary to assume that Loch Lomond occupies a trough that has been in existence only since some part of the Ice Age and that the present Loch Lomond catchment area (the Endrick system excluded) was preglacially part of three entirely independent drainage basins, all with their outflow to the east and ultimately no doubt to the North Sea. These were: (a) Glen Dochart and the Tay drainage; (b) Arklet-Katrine and Teith-Forth drainage; (c) Douglas-Luss system (and possibly the Fruin), to the Strath Blane gap and the Forth drainage.

Fig. 3. *(opposite)* Reconstruction of the preglacial drainage: 1. Suggested lines of preglacial drainage; 2. Preglacial divides; 3. General lines of strike-streams related to linear fault zones or weaker rock outcrops and presumably developed by adjustment to structure in preglacial times; 4. Preglacial divides related to 3 at head of Loch Long; 5. Glacial breaches in 2 or 4; *(see p. 34)*; 6. Ice-modified cols in 2 or 4; 7. Area probably captured preglacially from the Fruin-Douglas streams by the "Loch Long" subsequent; 8. Area possibly captured preglacially from the Inveruglas - Arklet drainage by the "Loch Long" subsequent.


220
230
240
730
720
710
700
690
GLEN LOCHY
TO GLEN ORCHY & LOCH AWE
STRATH FILLAN
TO THE TAY
GLEN DOCHART
Ben More
GLEN FALLOCH
TO LOCH FYNE
STRATH DUBHE-INSEG
Ben Chabair
TO BALQUHIDDER, BALVA & LOCH EARN
LOCH SLOY
Ben Vorlich
LOCH KATRINE
LOCH ARKLET
Inverugles
Ben Ime
TO THE TEITH
Arrochar
Ben Lomond
LOCH LOMOND
GLEN DOUGLAS
TO THE FORTH
GLEN LUSS
GLEN FRUIN
?
TO STRATHBLANE & THE FORTH
VALE OF LEVEN
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0 1 2 3 4
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BLL, HAM, 1958.

In making this reconstruction some additional points may be noted regarding both (a) and (b).

(a) GLEN DOCHART AND THE TAY DRAINAGE. No reason exists for regarding the preglacial drainage beyond the head of Loch Lomond as other than the headwaters of Glen Dochart. The latter was an ample valley opened up along the outcrops of weaker schists near the horizon of the Loch Tay Limestone, and the great peat-covered flats at 1,600-1,700 feet north of Glen nan Caorrunn, the mature topography at 1,300-1,500 feet around Crow Knowe (355240), or at 1,400 feet near Loch Essan (413284) indicate how widely open this preglacial valley must have been. At its head stood Ben Lui (3,708 feet) and the drainage of the northern flank of this mountain goes by the River Cononish to Strath Fillan and Glen Dochart still. We here suggest that the drainage of the southern flank went in exactly similar fashion by the line of Glen nan Caorrunn and Glen Falloch. Glen nan Caorrunn and Lairig Arnan both show anomalous north-easterly stretches in their lower reaches before each turns sharply south-eastwards to descend rapidly into the Falloch. The north-easterly trending reaches almost certainly preserve the earlier drainage direction towards Glen Dochart. It is our belief that ice from the north accumulated in these valleys when they still contained the headwaters of the Falloch-Dochart drainage. Extensive over-running by ice of the watershed to the west and south breached it at several points. The breaches are numbered in Figure 3 to correspond with the following text numbers:

(i) at 302302, 265278 and 240245, into Glen Lochy,

(ii) at 209210, where a breach was opened to the Loch Awe basin (though the westerly drainage of this gap now goes to the Shira),

(iii) at 240200, where what was once the most westerly Tay headstream (Allt an Taillir - 210227) has been diverted through a deep and spectacular breach into Glen Fyne: the falls at 243215, where Allt an Taillir descends 300 feet in less than half-a-mile, clearly mark the point of diversion,

(iv) at 280180, between Lairig Arnan and the Allt na Lairige tributary of Glen Fyne,

(v) through Strath Dubh-uisge—a valley with a structural trend, probably developed preglacially as a tributary of the Falloch-Dochart-Tay, whence there are deep breaches at 250115 to the Kinglas and Loch Fyne and, at 285115 (Loch Sloy) to the Inveruglas, and

(vi) between the Little Hills spur (2,602 feet) of Ben Vorlich on the west and Stob nan Eighrach (2,011 feet) on the east, *i.e.* at the point now marked by the Pulpit Rock and Rudha Ban on promontories of Loch Lomond.

The Allt an Caorrunn (270220), the Fion Glen (320225), the Allt Arnan, the Strath Dubh-uisge (290152) and the streams at 310138 and 335175 still display the original direction of flow; but the whole of the Falloch below its bend at 370237 and Loch Lomond north of the Pulpit Rock represent reversal of drainage.

(b) ARKLET-KATRINE. It is instructive to compare, on the map, the reconstructed Inveruglas-Arklet drainage area with that drained preglacially and today by the headstreams of the Balva to Loch Voil and Balquhidder. In each case a west to east trunk receives short tributaries from left and right which increase in length eastwards, but the Arklet system extends further west. The watershed between these and the Falloch-Dochart-Tay drainage is remarkably straight, parallel to the latter, and contains many of the highest summits of the region. The bounding watersheds thus converge westwards to one apex a mile

south-west of Ben Chabhair at the head of the Balva, and another at the Beallach a'Mhaim (262070) between Ben Ime, 3,318, and Ben Narnain, 3,036 feet. These watersheds had been dissected preglacially into a series of peaks and cols, the former rearing up to over 3,000 feet and the latter falling in many cases below 2,000 feet. The cols thus afforded passage for ice when the mountains were deeply invested, and field examination of the cols around Stob Binnein (435225) north of the Balva trough, *e.g.* Inverlochlarig Glen (420225), reveal a degree of modification by ice inversely proportional to altitude. Ice from the Balva trough, however, breached the southern watershed at 410150 below Stob a Choin and less effectively elsewhere, and, as has been previously described by one of us [18], found its main outlet by breaching the Ben Ledi-Stuc a'Chroin watershed at the site of Loch Lubnaig (575135), thus reversing the drainage of the whole of Strathyre and severing the Balva drainage from its original trunk–the Earn.

The events visualised in the Inveruglas-Arklet system are essentially similar–the breaking in of northern ice over the watershed at Loch Sloy and Pulpit Rock (compare Inverlochlarig Glen and Glen Ogle) and breaking out southwards into Loch Lomond at Rudha Mor (compare Loch Lubnaig). Two points of difference however deserve mention. Once initiated, the southward flow along the line of Upper Loch Lomond became by far the most powerful in the district, as is witnessed by the excavation of the trough more than 400 feet below sea level for eight miles of its length with a maximum depth of 623 feet. If we are correct in interpreting the level of the old valley over this part of Loch Lomond as being of the order of 900 feet at Inversnaid and rising southwards, it is clear that excavation of some 1,500 feet of rock has occurred here for several miles.

A further point concerns the relations with Loch Long. It seems possible that the col east of Dubh Cnoc (305085), which stands below 500 feet, marks the site of a former right-hand tributary of the old Inveruglas stream, and that headward erosion by a stream developing along the Loch Long-Glen Loin line led to the abstraction of this part of the Inveruglas system, but it is not certain that the reversal of drainage involved must be ascribed to ice action. Loch Long is so straight and its direction so similar to that of other fault-guided valleys in the south-west Highlands that it is probable that it is a true subsequent of fairly respectable antiquity. It is not impossible, as was suggested by H. M. Cadell, that Coilessan Glen (250016) is the head of a Glen Douglas decapitated by preglacial capture. Comparable piratical activities may have extended the Loch Long drainage basin as far as the present Glen Loin and the Arrochar Tarbert valley, which also corresponds with a structural line. If that is so a part of what is now the trough of Loch Lomond may have been annexed preglacially to the Loch Long catchment.

It remains to suggest why ice movement in the region of Loch Lomond should have been so powerful that it was able to create a through trough over twenty miles long by the integration of portions of three distinct drainage systems whose trunk streams ran from west to east, breaking powerfully through two major watersheds that similarly ran from west to east athwart its course. The reason is perhaps best

seen by considering the circumstances of a rather larger area. Loch Lomond, large as it is, is but one of a numerous series of some thirty-three glacial troughs – recently detailed by one of us [19] – that radiate from a tract of some 500 square miles of mountain and moorland traversed by the modern highway A82 from Tyndrum to the head of Glencoe. This region today lies at the heart of a much more considerable area of the south-west Highlands which may be defined by the generalised 100-inch isohyet. It is probable that in Pleistocene times also, it lay at the heart of a large region of very heavy precipitation, a region that for much of the actual glacial episodes constituted a great ice dome which buried deeply even the highest peaks (e.g. Clach Leathad 3,602 feet) in the central area. This ice dome discharged by outlet glaciers in all directions. Where these found valleys running in the right direction–*i.e.* radially from the region of maximum accumulation–they used and enlarged them. Such were the valleys now holding Loch Awe, Loch Fyne, Loch Long, Loch Katrine, Loch Earn, Loch Tay and Loch Rannoch. Where there were no suitably directed outlet valleys ice accumulated in the central area until it was able to override watersheds and create the outlets it needed. Loch Treig and Loch Ericht in the north, and Loch Lubnaig in the south-east are examples already recognised and described [20]. To this group we wish now to add Loch Lomond, in some ways the most impressive of all. Indeed its very size and importance have delayed recognition of its true nature and recent origin.

Finally, the point may perhaps be made that, though we here claim the destruction of two watersheds by the Loch Lomond ice and the replacement of a valley falling northwards at levels between 900 and 1,500 feet by an over deepened trough reaching 500 to 600 feet below sea level, we do not imply that ice erosion of this intensity was other than strictly localised. We have already suggested that in a number of places in the immediate neighbourhood of Loch Lomond it is possible to recognise elements of the preglacial topography, albeit somewhat ice-moulded and degraded. We are strengthened in the conviction that these occurrences are indeed what we claim, by the presence in some localties in the Loch Lomond area of materials that can only have been derived from the preglacial weathered mantle, unless the Great Interglacial were long enough and warm enough to create a substantial regolith by sub-surface rotting with numerous corestones. At and near the summit of Ben Ime may be found core stones, showing onion weathering, of a gabbroid dyke rock, and on certain dyke-outcrops pockets of richly ferruginous fine-grained products of weathering are locally exposed in the cliffs. Equally striking are the instances, by no means rare, of boulders of intermediate and basic igneous rocks in a deeply weathered condition that occur in the morainic drifts of Glen Croe. Some of these are of large size and exhibit hard cores enveloped by onion skins of more rotten rock; some are rotten throughout and of a gingerbread consistency that can be readily broken between the fingers: others are so rotten as to be barely distinguishable from the matrix. Since other boulders of the same rocks in the same deposits are hard and unweathered it is clear that the rotting took place before incorporation. They clearly imply that somewhere

very near at hand the ice of the last glaciation found remnants of the deeply rotted regolith of preglacial (or possibly Great Interglacial) times, which had been spared by the ice of successive glacial episodes because it lay a little beyond the great avenues of ice flow. Ice erosion appears here as elsewhere in the Highlands to exhibit striking variations in intensity over quite short distances.

The extinction of eastward flowing drainage by west-coast streams is a constantly recurrent theme—and perhaps the major one—in the geomorphological history of upland Britain. Thus the eventual disruption of the drainage systems, whose headwaters, we believe, once drained the area now occupied by Loch Lomond, was certainly inevitable. In the event, if our hypothesis be correct, the climatic accident of glaciation was responsible for the final act of disruption and diversion to the Clyde. In the story of the evolution of Scottish scenery this diversion is but a paragraph in the chapter on the Clyde drainage; in particular the events which we have sketched depend on the presumed earlier (possibly mid-or late- Tertiary) integration of Firth of Clyde with the estuary and inland river; moreover the origin of the connecting link, the Vale of Leven, remains obscure. If our hypothesis stimulates further interest in these problems, as well as in those of the Loch Lomond basin, it will have been justified.

[1] Kinahan, G. H., The Valley of Loch Lomond, *Trans. geol. Soc. Glasg.*, 1873, IV, (2), p.181.

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[8] Geikie, J., *op. cit.*, p.229.

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[15] Cadell, H. M.,*op. cit.*, see folding map opposite p. 349.

[16] Bremner, A., *op. cit.*, p. 56.

[17] Bremner, A., *op. cit.*, p.57, shows the original drainage passing to the north of the Campsies along the Fintry-Carron valley line.

[18] Linton, D. L., Some Aspects of the Evolution of the Rivers Earn and Tay, *S.G.M.*, 1940, LVI, pp.1-11 and 61-79; see particularly p.74.

[19] Linton, D. L., Radiating Valleys in Glaciated Lands, *Tijdschrift van Het Kon. Ned. Aardrijkskundig Genootschap*, 1957, Deel LXXIV, pp. 297-312, especially Fig. 2.

[20] Linton, D. L., Watershed Breaching by Ice in Scotland, *Trans Inst. Brit. Geogr.*, 1949, pp.12-14.

THE MONTFERRÉ MINING REGION LABRADOR-UNGAVA

GRAHAM HUMPHRYS

THE Montferré region of Labrador-Ungava covers some 2,000 square miles of the southern end of the Labrador Trough, overlapping the Quebec-Labrador boundary roughly 200 miles north of Sept Iles (Fig. 1). It is therefore, only a relatively small part of the interior of this vast north-east peninsula of North America. Yet it is of particular interest to the geographer, not only because production plans for the region anticipate capture of up to 15 per cent of the North American iron-ore market, but because it exhibits features directly attributable to its remote location beyond the limits of continuous settlement. Reserves of ore are measured in thousands of millions of tons, assuring the basis for a long mining life ; since the developments are very recent, however, and production is not scheduled to begin until 1961, it provides an opportunity of examining the processes at work in the development of pioneer mining areas.

The region, although considered remote today, was well known to the *'coureur de bois'* of the seventeenth century, who, working mainly from the town of Tadoussac at the mouth of the Saguenay, traversed the whole of the southern watershed, trading and trapping furs. The first scientific report on the local minerals was made by the federal geologist A. P. Low, who carried out a number of reconnaissance surveys across the peninsula in the eighteen-nineties. During the following forty years, several expeditions sent to report on Low's findings discovered considerable deposits of iron formation containing 35 per cent iron, but the low grade of the ore together with the remote location of the area dismissed hopes of development.

The modern mining period really began in 1936, when the Labrador Mining and Exploration Company began prospecting on a 20,000 square mile concession in the centre of the peninsula, granted to them by the Newfoundland government. Their property extended from the Quebec boundary near Knob Lake, as far south as the eastern end of the Montferré region near Wabush Lake. The company actually started operations in the latter area, but with the decision in 1945 to develop the high-grade iron ore near Knob Lake, the Montferré region was once more neglected. Little more of interest occurred until 1952 when much of the activity which has continued through to the present time began.

Between 1936 and 1952 changes significant for the Montferré region had been taking place in the North American iron-ore industry. Two of these were, and are, of particular importance, the improvements in the technology of beneficiation [1], and the depletion of the easily accessible, high-grade sources of iron ore for the North American steel industry. They are indissolubly linked ; with the decrease in high-grade ore reserves, vast sums of money have been spent on perfecting cheap, efficient means of beneficiation. As mining of the Great Lakes ore became more difficult it rose in price, closing the gap between the

cost of deep open-cast, unprocessed ore and shallow open-cast, beneficiated ore. Today the gap still exists, but it is more important for the companies without high-grade reserves than for others with them. The former are the ones seeking the easily mined low-grade ores to fulfil their future needs. The improvement of the techniques used to raise the grade of the ore is having repercussions hitherto unconsidered. The iron and steel industry is highly capitalised, needing

Fig. 1. The location of the Montferré region in Labrador-Ungava

the highest efficiency of operation to put the investment to good use. When beneficiation is used, the material that reaches the furnace is already a partially manufactured product, with very important advantages over natural ore. Not only is the iron content much higher (generally 65 per cent as opposed to 50 per cent in North America), but its constitution can be kept within narrow limits, and its physical structure is more suitable for furnace practice. With such a uniform high quality of raw material, smelting can be much more easily controlled, resulting in a superior end-product. Unprocessed iron-formation is handicapped by its inferior and variable quality, and increasing costs with deeper mining. Inheriting all the advantages of

mining technique and benefitting from the lack of previous exploitation, low-grade ores are finding the cost of processing a decreasing handicap. This has been reflected by the increase in the amount of beneficiated material shipped annually from the United States mines, rising from 23 per cent of the total in 1947 to over 40 per cent of the total in 1957. In the latter year, just under three tons of raw materials were used in the average United States blast furnace for each ton of iron produced,

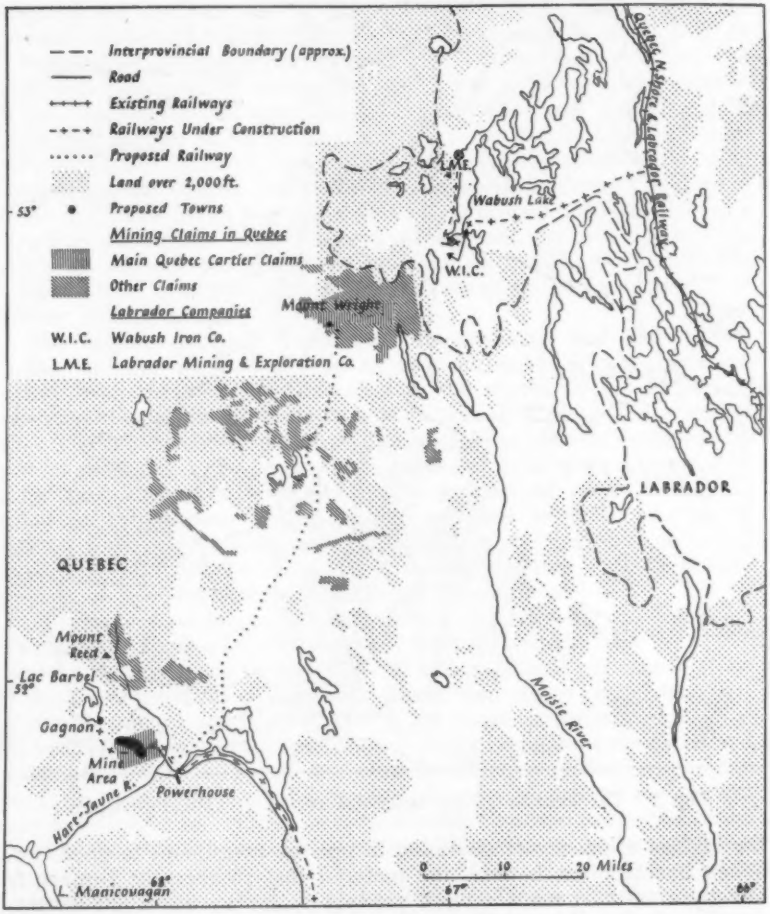


Fig. 2. Mining activity in the Montferré region.

a lower proportion than ever before [2, 3]. These changes have caused a re-assessment of the value of low-grade iron deposits, and a resulting scramble by the iron and steel industry to secure adequate reserves in North America. The Montferré region is one of the results of this scramble.

The iron formation which has attracted so much attention to the

region occurs as bands within the underlying highly contorted and metamorphosed assemblage of Upper Precambrian sediments. The iron ore, found within the formation as specular haematite with quartz or as a magnetite-haematite facies, contains an average of 33 per cent iron, and is considered exploitable only where large quantities are accessible to surface mining operations. Lying as it does along the watershed of the Ungava Bay, St Lawrence and Atlantic drainage systems, the region has a highly varied relief averaging 2,500 feet above sea level. Near Wabush Lake, high rugged hills occur, grading off westward to an uneven rocky plateau near Mount Wright. Extensive areas of glacial drift are masked by muskeg, while in the extreme south-west deep dissection has resulted in a high relative relief of up to 1,500 feet.

The crest of the Laurentide scarp lies immediately to the south at a height of just over 3,000 feet, and has been deeply dissected by the youthful streams which cascade down glacially scoured valleys, so that the whole zone between there and the Gulf of St Lawrence offers a major obstacle to the penetration of the interior. It is in this section that construction of transportation facilities is most difficult and expensive. Prior to 1954 the only means of reaching the region were by air from Sept Iles, or by canoe up one of the many rivers. The use of planes, float-equipped in summer, ski-equipped in winter, is greatly facilitated by the many lakes, but canoeing entails so many long portages that it has been little used since 1933. The whole region was uninhabited before mining began, being crossed only occasionally by the semi-nomadic Montagnais Indians on their hunting trips from the North Shore. In 1954 the completion of the Quebec North Shore and Labrador Railway, which bounds the region in the north-east, stimulated activity around Wabush Lake by providing cheaper access. The distance involved, however, gave this route little cost-advantage over air transport in the south-western part of the region.

The present mining activity was initiated in 1952, two years before the Q.N.S. and L. Railway was completed. In that year the Quebec Cartier Company (a direct subsidiary of the United States Steel Corporation) staked claims on the Quebec side of the boundary between and around Mount Wright and Mount Reed (Fig. 2). Subsequent geological surveys showed the claims to cover deposits of over 2,000 million tons of ore averaging 32 per cent iron, and in 1957 it was decided that the Mount Reed deposits would be brought into production. Work was begun immediately to survey the route for a new 197-mile railway to the area from Shelter Bay on the St Lawrence, and in 1958 a road was completed from Shelter Bay to Mount Reed greatly facilitating the work. At the present time a permanent town-site with a plan similar to Schefferville's [4], is being built on the shores of Lac Barbel. The railway is under construction, and a new dock capable of accommodating ships of up to 100,000 tons will be created at Port Cartier near Shelter Bay. Approximately two-hundred million dollars will be invested in these facilities before mining can begin. To recover this large sum within a reasonable period, from such a low-cost product as iron ore, operations will necessarily be on a large scale. Initial production starting in 1961 is set at eight million tons of concentrate

a year, derived from twenty million tons of natural ore. Beneficiation will entail crushing the ore to a consistency of coarse sand and removing the gangue, which will be mainly quartz, by the Humphreys spiral system based on the different specific gravity of the iron-bearing material and the unwanted rock. The resulting product, containing roughly 65 per cent iron and 4 per cent water, will be transported by rail to Port Cartier, and from there by ship to the United States and Europe. Recent surveys suggest that navigation out of the Gulf of St Lawrence will be possible all the year round, making this the only major iron-ore region in North America shipping during the winter months. Plans for future development of the Quebec Cartier properties include the extension of the railway north to Mount Wright to exploit the northern ores.

The other two major mining developments at present nearing the production stage are both on the Labrador side of the boundary, between it and the Quebec North Shore and Labrador Railway. The Labrador Mining and Exploration Company has renewed exploration of the south-west portion of the original concession granted to them by the Newfoundland government in 1938. The area of interest is bounded by the provincial boundary on the west, and Wabush Lake on the east. By 1957 surveys had revealed local deposits of over 1,000 million tons of ore grading 35 per cent iron, and in 1958 some of the original staff from Schefferville were moved to the area to supervise the work. In 1959 the company, in conjunction with the Iron Ore Company of Canada, will invest over one million dollars in exploration, and trailers will be used to provide better accommodation for the senior staff. Although no plans have been announced, it is understood that production will begin by 1962. Before this will be possible a rail link to connect the area with the Quebec North Shore and Labrador Railway some forty miles away will have to be constructed. Agreements have already been reached with the Wabush Railway Company for the use of that part of the rail line which it is building to Wabush Lake for the Wabush Iron Company, thus saving the cost of duplicating the line. Preliminary estimates for the whole project call for the investment of some one-hundred-and-fifty million dollars to start production at six million tons of concentrate a year. The ore will be exported through the Iron Ore Company of Canada's existing port facilities at Sept Iles.

The third development already well-advanced is that of the Wabush Iron Company, which holds leases on the east side of Wabush Lake. Work began there in 1952, and in the following four years eight million dollars were invested to outline reserves estimated at over 1,000 million tons of ore averaging 38 per cent iron. The Wabush Iron Company, owned jointly by Pickands Mather and Company with United States associates and the Steel Company of Canada, leased the deposits in 1957. Work on the rail line to link the area by rail to the Quebec North Shore and Labrador Railway in the east begun earlier, was continued, becoming a joint undertaking later with the participation of the Iron Ore Company of Canada, who will use the line for the movement of ore from its deposits further west (see above). Beneficiated ore will be moved by rail to Sept Iles, to be exported from there to markets in the United States and Europe. Production is expected to

start at eight million tons of concentrate a year beginning in 1962.

Two other major United States iron and steel companies, the Jones and Laughlin Steel Corporation and the Cleveland Cliffs Iron Company, have jointly financed a survey of a lease near Mount Wright, where over 1,000 tons of ore capable of yielding 335 million tons of concentrate have been discovered. No plans for development have yet been announced. The W. S. Moore Company, which has also had experience in the United States iron trade, has optioned a lease covering small deposits of ore near Mount Wright. There is seasonal activity on most of the other claims held in the Quebec section of the region, but it is thought that production from these will take place only after the major companies begin exporting. Many of these claims seem to be held in the hope that the larger neighbours will become interested enough to develop them, with a resulting profit to the holders : they are in other words, purely speculative. Some of the claims, however, probably cover sufficient ore to justify exploitation, but only if the heavy capital costs of long-distance railway lines, and other necessary facilities are borne by others. Once these are provided, the threshold for exploitation in terms of ore tonnage will naturally be lowered quite considerably, since it will then be possible to buy the services such as electricity, transport, and beneficiation from others, without the large initial investment. Once the region enters production therefore, it is to be expected that the number of operating companies will increase.

The main problem faced by all the companies is that of transport, the solution of which will have considerable bearing on the development of the region as a whole. For initial exploration work, air transport proved adequate, and is still used by those companies in the prospecting stage. For the three major companies, however, other means are needed to handle the increased freight traffic. Quebec Cartier have already built a road north from Shelter Bay to Mount Reed, to supply material to the railway during construction, and to the mine site before the latter is completed. The Wabush Iron Company has also built a road from the Quebec North Shore and Labrador Railway to Wabush Lake, but because of the greater distance involved. Labrador Mining and Exploration Company, even in the Spring of 1959 were still carrying material from the track to their base camp by air. In considering the export of ore the problem is somewhat different. The cost of railway construction across the north-south oriented and dissected landscape of the western part of the region, and the distance, prohibit the use of a feeder line onto the Quebec North Shore and Labrador Railway. Instead the Mount Reed ore will be carried on an entirely new railroad being built north from Shelter Bay. As a private line there will be no obligation for it to carry other companies' material, though it is anticipated that agreements to this end will later be drawn up. The railway will, however, still have to cross the Laurentide scarp, and the engineering costs for this section will take a large share of the two-hundred-million-dollar total expected outlay for the mining project. Eventually the line will be extended to tap the Mount Wright holdings of Quebec Cartier, providing other companies in that area with a stimulus to develop, but also introducing a tendency to integrate them into a western sub-region. For the properties on the Labrador side of

the boundary, the short distance of forty miles and the lesser relief make the construction of feeder lines to the Quebec North Shore and Labrador Railway a much more practicable proposition. Work has already begun on a line by the Wabush Iron Company, and the Iron Ore Company of Canada has negotiated an agreement for an extension to its property. The major drawback of this feeder line is the capacity of the existing line. To allow passage of the extra material further double-tracking will be necessary, particularly in the scarp section to the south, precisely where engineering problems and construction costs are greatest. Freight charges will presumably have to be increased to meet them, but since the Quebec North Shore and Labrador Railway is a wholly owned subsidiary of the Iron Ore Company of Canada, such increases would probably be felt most by the other users of the line. The total cost of the new railways into the region will be in the order of two-hundred million dollars : investments which in part account for the large scale of the operations. When the region eventually has several producers, there is little doubt that an integrated road-network will be constructed, linking up the sub-regions to produce a more coherent whole than is at present observed. One further aspect of transport is important. The beneficiated material will probably contain under 4 per cent water, allowing it to be transported in winter without freezing into a solid mass. With year-round navigation out of the Gulf of St Lawrence, there will be no seasonal shut-down as at Knob Lake, where the 14 per cent water-content of the ore allows it to freeze in transit to Sept Iles, prohibiting winter haulage.

Within the Montferré region at least three, and probably five, new settlements are planned. At Lac Barbel, Quebec Cartier have already begun building a town named Gagnon, the Wabush Iron Company have reserved part of their property as a town-site, and the Iron Ore Company of Canada have several potential town-sites under consideration. The distance from Mount Reed to Mount Wright suggests that Quebec Cartier will erect a subsidiary settlement to serve the latter area, and other companies will probably house their own workers near each mine. Labour for the operations will be recruited by Quebec Cartier in the Montreal lowlands, and it is interesting to note that married men with families of at least two children will be preferred. The company hopes in this way to overcome the problem of high labour turnover so often experienced in northern mining towns. There is little doubt that the inhabitants of the settlements in the region, as at Schefferville, will be predominantly French speaking, further expanding the limits of French Canada into Northern Quebec.

The actual mining landscapes will reflect to a certain extent the remote location and type of ore mined. To repay the huge capital investments within a reasonable period, operations will have to be on a large scale ; a fact further accentuated by the exploitation of such a low-cost product as iron ore. The latter in particular, means that open-cast mining, preferred anyway, will be absolutely essential. The beneficiation carried out at the mines will result in large quantities of waste material which, unless there is careful planning, could despoil quite large areas. Concern over this matter tends to be lessened by the domination of the developments by companies with long experience

in iron mining in the United States. Their presence can be explained by the high cost of initiating exploitation, and by the nature of the North American iron and steel industry. To raise the large sums of money needed, investors have to be assured of the success of the project, normally achieved by the drawing up of long-term marketing agreements for the ore. Since there is virtually no free market for iron ore in North America, the only way to get such agreements is by the participation of major iron and steel companies, as has happened in the Montferré region. Such integration is fairly common in contemporary mining developments, and all the successful mines in Labrador-Ungava are linked with United States industry in this way.

The Montferré region seems to be moving through the second phase of pioneering associated with northern mining activity. The first phase was the seasonal activity of the true prospecting-exploration, when the area was inhabited only during the summer months. Now there is year-round occupation, though still in such a form that little evidence would remain if it suddenly ceased. Once the towns are established, however, the pioneer stage will be at an end: facilities will be provided equal to or superior to those found in settled areas further south, and it will become an outlier of civilisation with an urban population in an otherwise uninhabited landscape. Though small the population will be making a major contribution to the North American economy, carving yet another new region out of the Canadian north.

The writer wishes to express his gratitude and indebtedness to the following for the co-operation and assistance in providing help and information: Dr J. A. Retty, Consulting Geologist, Montreal. Officers of the: Canadian Javelin Company; Iron Ore Company of Canada Limited; Labrador Mining and Exploration Company; Normanville Company Limited; Wabush Iron Company; Quebec Geological Survey, Montreal.

[1] Beneficiation is the upgrading of ore by separating the mineral-bearing material from as much as possible of the surrounding rock mined with it, the latter generally termed the gangue.

[2] *Steel Facts*, No. 150, June 1958, p.7. New York: American Iron and Steel Institute.

[3] For recent development of iron-ore beneficiation in the Great Lakes area of North America, see C. F. Kohn and R. E. Specht, The mining of taconite, Lake Superior mining district. *Geogr. Rev.*, 1958, 48 (4) : 528-539.

[4] Humphrys, G. Schefferville, Quebec : A New Pioneering Town. *Geogr. Rev.*, 1958, 48 (2) : 151-166.

GLACIAL RETREAT STAGES IN KINROSS-SHIRE

JANE M. SOONS

THE largest part of the county of Kinross is formed by the plain, of moderate altitude but of low relief, which stretches westwards for a distance of some seven or eight miles from Loch Leven (Fig. 1). This is an area of abundant glacial deposits, both stratified and unstratified, which have been on the whole but little modified since the ice of the last glaciation withdrew from the area. Across it flow a number of streams of low gradient, following more or less easterly courses towards Loch Leven. Surrounding it on all except the western side are hill-masses of contrasting character – the Ochils on the north, the Lomond Hills on the east, Benarty and the Cleish Hills on the south. Of these hill-masses, all but the Ochils rise sharply from the plain, overlooking it by steep uninterrupted slopes. In contrast, the Ochils rise relatively gently, and several broad valleys descend from north to south towards the plain. This contrast is of considerable significance in the tracing of glacial retreat stages in the area. On the long slopes from the Ochil watershed to the plain the successive positions of the retreating ice-edge are marked by a series of meltwater channels which provide some fine examples of this class of feature. Along the steeper slopes of the other hill-masses the shrinking of the ice-mass was accompanied by only a slight horizontal change in the position of its edge, and meltwater channels and related features are rare.

There has been no general agreement amongst previous writers as to the exact significance of the depositional forms of the plain of Kinross. Sir Archibald Geikie in 1900 noted the tendency of the sands and gravels to be arranged "in long, narrow, undulating ridges", but was content with description and made no attempt to explain the forms. [1] J. W. Gregory, in a catalogue of the Scottish kames, ignored most of the area but regarded the long ridge known as the Drungie Knowes (Fig. 2) as a kame "formed on the south side of a glacier from the Ochils that came down the South Queich valley and ended on the plain between the Crook of Devon and Kinross". [2] Two years later (1928), J. K. Charlesworth described the same feature as an esker formed by a sub-glacial stream, and envisaged the retreat of an ice-front across the area from east to west, interrupted by halts giving rise to moraines near Milnathort and to "marginal accumulations" near Crook of Devon. [3]

The present writer's investigation of the area suggests that no support can be given to Gregory's conception of a glacier from the Ochils utilising the South Queich valley. For two miles above its outlet onto the plain this valley is a typical meltwater channel and can never have been occupied by ice; nor is there evidence of the development of local glaciers within the Ochils, which possess no corries. As Charlesworth suggests, the ice which spread over the plain of Kinross was probably a branch of the large glacier which occupied the lower Forth valley. Carboniferous material in outwash deposits in the entrance to Glen Devon shows that this ice certainly spread as far as the western edge of the plain, and while, to judge from the

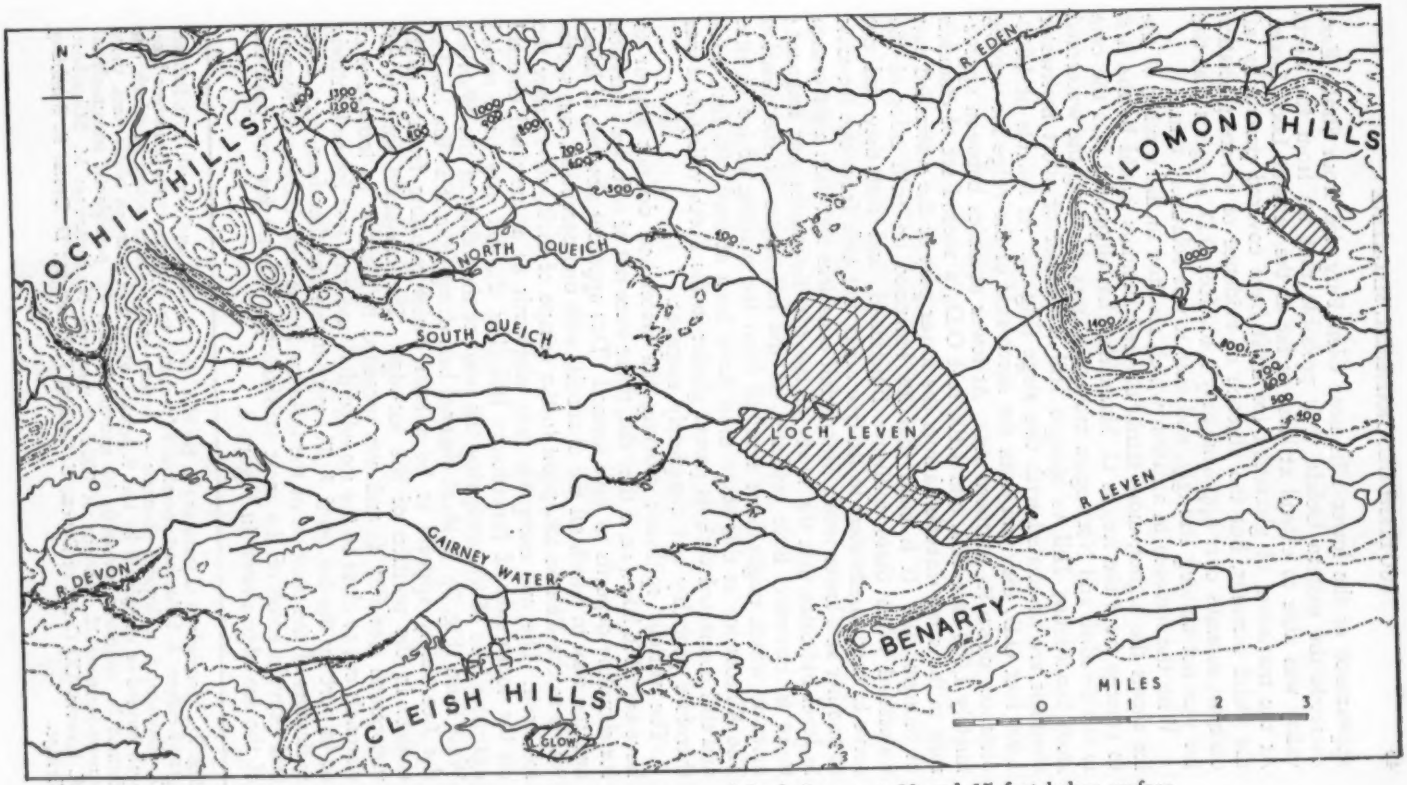


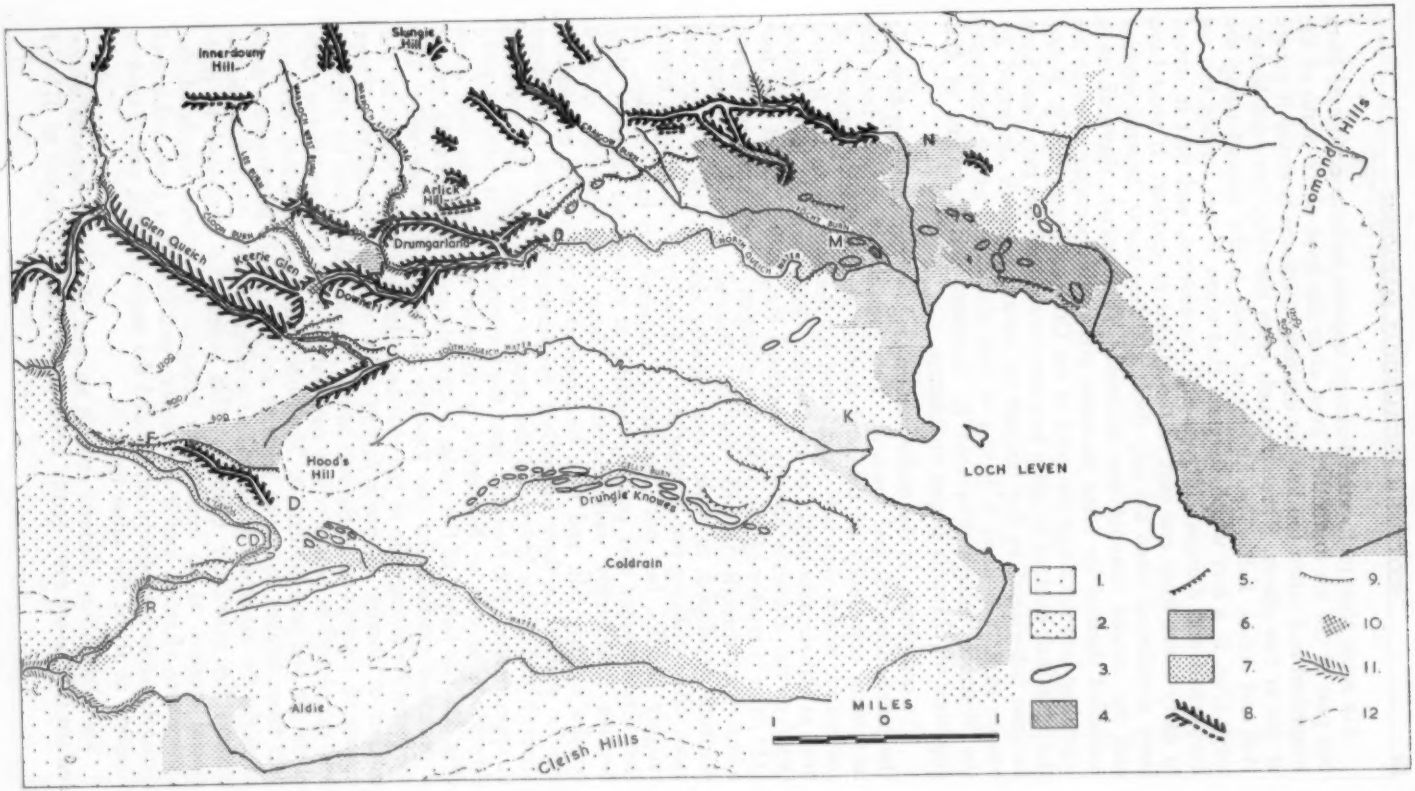
Fig. 1. Relief and drainage; submarine contours of Loch Leven at 10 and 15 feet below surface.

appearance of the lower hills near Glen Farg, ice from Strath Earn overrode the eastern Ochils, it is probable that ice from the Forth valley was able to extend at least as far as the present Loch Leven. At the maximum of glaciation ice must have covered practically all the Ochil summits, but the absence of evidence of severe glaciation on most summits over approximately 1,400 feet O.D. suggests that this ice was not moving strongly, and that it was relatively thin.

With the increase in ablation which resulted in the waning of the ice sheets the higher, more thinly covered summits would be the first to emerge from the ice, as C. Mannerfelt has suggested was the case in the Swedish and Norwegian mountain areas. [4] Along the watershed from Innerdouny Hill to Slungie Hill a number of short meltwater channels are associated with this stage (Fig. 2). At heights of 1,300-1,400 feet O.D. they run from the north side of the ridge for varying distances down its southern side. At lower altitudes between approximately 1,000 feet O.D. and 1,100 feet O.D., a second set of channels runs in the same direction across the lower part of the watershed east of Slungie Hill. It is clear that ice remained on both sides of the watershed when these spillways functioned, and that they did not serve to carry meltwaters to ice-free areas, but only from one ice-mass to another at a lower level. Mannerfelt considers that such a difference in level indicates that the lower of the two ice-masses was stagnant; there is, however, little evidence on the hill slopes of the ablation moraine which might have resulted from the wasting of ice *in situ*. The Kinross ice at this stage must have been at least 600 feet thick and still connected with its parent glacier in the Forth valley, and was therefore probably not completely stagnant.

The various spillways crossing the watershed do not appear to have ended in lakes, or, if they did, these were not of sufficient duration for shoreline deposits to have formed. This apparent absence of lakes, and the way in which all the channels, with one exception, run southwards to the Kinross ice, point to the escape of meltwaters under the ice itself. The one exception runs eastwards as a one-sided channel on the south side of Innerdouny Hill (Fig. 2), and may have ended against a lobe of ice occupying the head of the valley of the Warroch West Burn (Fig. 3). A short channel branching from it at the head of the Lee valley appears to be a later outlet resulting from a slight change in the position of the ice-edge. The one-sided form is not uncommon (see Fig. 2) and was regarded by Barrow as indicative of channels cut so close to the ice-edge that one wall was formed entirely or in part by the ice itself. [5] These channels are therefore very exact indicators of the position of the ice-edge at the time they were formed and provide some of the most satisfactory evidence for the positions of the ice-edge shown in Figure 3.

Fig. 2. Morphological features: 1. boulder clay; 2. sand and gravel; 3. individual gravel ridges; 4. Milnathort moraine; 5. probable ice-contact slope; 6. former lake; 7. alluvium; 8. meltwater channels — broken line indicates points at which one wall formed or completed by ice; 9. terrace edges and river-cut bluffs (incl. those formed by meltwater streams); 10. corrom divides; 11. post-glacial stream-glacial stream-incision; 12. contours at 300-foot intervals. N. Netherby; M. Milnathort; K. Kinross; CD Crook of Devon; C. Carnbo; F. Fossoway; D. Drum; R. Rumbling Bridge.


Innerdouny Hill
Slunnie Hill
Artlick Hill
Glen Quaich
Keeper Glen
Drumgarland
Hood's Hill
Drungie Knowe
Coldrain
Aldie
Cleish Hills
LOCH LEVEN
Lomond Hills
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For some time meltwater drainage appears to have continued from one part of the ice to another, even after the level of ice north of the watershed had fallen too low for drainage southwards across it except at one or two places. Three channels cross the ridge between Slungie Hill and Arlick Hill. The highest of these is the second along the ridge (Fig. 2) a fact which suggests that when it was formed the col between it and Slungie Hill was still ice-covered, and that it served to carry water from one part of the glacier to another. It must have been abandoned when the col, about 100 feet lower, became ice-free and the second channel was initiated. This extends downhill as a one-sided channel for some distance, presumably running close to ice extending into the col at the head of the Craigow Burn (Fig. 3). Below the 1,000-foot contour it again becomes two-sided, and may here have become sub-glacial in the manner of certain channels described by Sissons in East Lothian. [6] It was in turn abandoned as ice occupying the Warroch valleys decreased in thickness and the third of this sequence of channels began to function.

The complexity of the meltwater drainage-system increases towards the junction of hill and lowland. This presumably reflects both the increasing complexity of the land surface and increasing amount of meltwater, which was now augmented by drainage from the ice-free area as the streams began to re-establish themselves. At levels below those of the channels already described (*i.e.*, below about 900 feet O.D.) the character of the spillways changes. There are few, if any, which lead directly towards the ice. Instead, a series of marginal channels developed, in some cases running close to the ice-edge, but more often utilising pre-existing cols and valleys to take up a course roughly parallel, but not immediately adjacent, to the ice-edge. At first discontinuous and possibly leading to sub-glacial channels, they become increasingly well-integrated. These later channels show a regular easterly fall, and may be assumed to reflect the gradient of the ice surface in their immediate neighbourhood. The Hattonburn channel, one of the longest in the area, is of this type. Commencing at approximately 650 feet 0.D. near the Craigow Burn, it runs obliquely downslope to end at Netherton, a distance of two-and-a-half miles (Fig. 2). The height of the outlet is approximately 420 feet O.D., giving a probable gradient for the ice-edge of 90-100 feet per mile. The southern, ice-facing side of the channel is broken in two places by the intakes of shorter channels falling more steeply downslope. These appear to correspond to the sub-lateral channels described by Mannerfelt, developed at points where meltwaters were able to lift the edge of the ice and pass beneath it. The floor of the main channel continues past these intakes, however, without any noticeable interruption, such as might be expected if water had ceased to flow down the section beyond the subsidiary channel. This cannot be attributed to post-glacial erosion, as no one stream occupies the whole length of the Hattonburn channel, and it is therefore probable that these sublateral channels never completely superseded the main channel, and ceased to function at about the same time.

The Hattonburn channel ends at an area of alluvial deposits whose surface falls away very gently towards the south. (Heights of 411-414

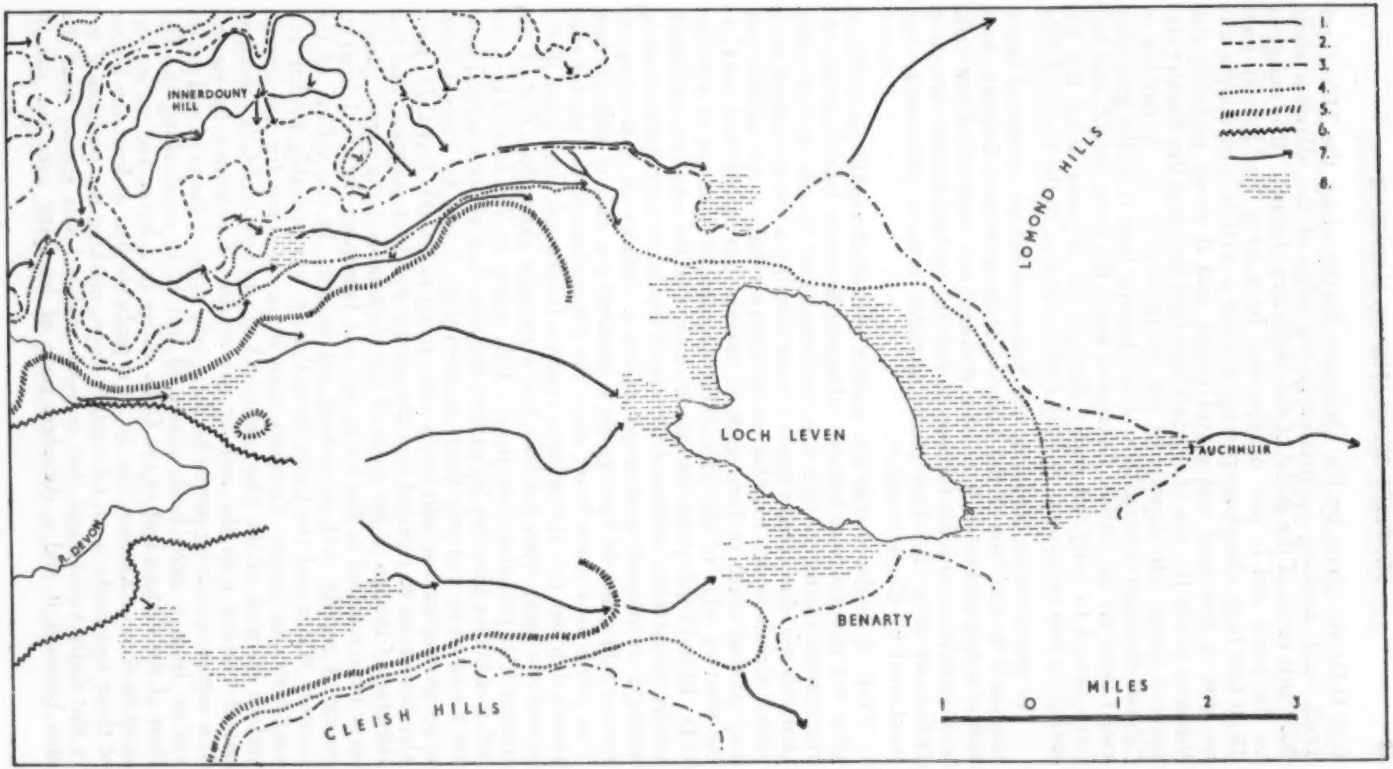

Fig. 3. Probable successive positions of ice-front : 1-6. positions of ice-front; 7. lines of meltwater drainage; 8. former lake.

feet O.D. are given by the Ordnance Survey along the Milnathort-Perth road, marking approximately the edge of the alluvium about 800 yards south of the outlet of the meltwater channel). It is margined on the north and in part on the west by a steep boulder-clay bank 15-20 feet high, elsewhere passing without a well-defined margin into an area of low sand and gravel ridges, and it seems probable that this area marks the site of a small lake held between the boulder-clay covered lower hill slopes and the ice-front (Fig. 3). A number of "glacial drainage channels" are shown leading from it on the geological map : these are all shallow features at much the same height, and may have served to carry off water through the deposits along the ice-margin to join meltwaters flowing north-eastwards to the Howe of Fife.

The gravel ridges bordering the Netherton flat are continued south-eastwards to the foot of the Lomond Hills at Wester Balgedie by a belt of ridges and mounds, of both stratified and unstratified materials, and north-westwards by further mounds in the boulder-clay area near Milnathort (Fig. 2). This broad morainic area is presumably that mentioned by Charlesworth [3].

There is evidence that the glacier decreased rapidly in thickness after the moraine was formed. Marginal drainage ceased to use the Hattonburn channel, which was succeeded first by one or two minor channels not shown on Figure 2, and later by a route marked by a lateral terrace which may be traced from an early outlet of the spill-way passing north of Drumgarland, where it is at 550 feet O.D., to the western edge of the Milnathort moraine at a height of 490 feet O.D. Beyond this point the terrace is lost in the moraine, and melt-waters presumably continued by one of the many depressions running amongst its mounds and ridges. Over a distance of two miles the terrace falls some 60 feet, giving a gradient per mile of only 30 feet. This points to a much lower slope for the surface of the glacier than obtained when the Hattonburn channel functioned, and even if the ice-surface away from the hills had a stronger slope than that of the terrace it is probable that Hood's Hill, rising to 734 feet O.D.—over 300 feet higher than the Milnathort moraine—had either emerged from the ice cover or was only thinly covered (Figs. 3 and 4). The thickness of ice over other low hills in the area, rising to 500-600 feet O.D., must also have been so reduced that the glacier was here stagnant, and this thinning of the ice in the parts of the plain nearest the parent glacier must have resulted in the ice to the east becoming detached from its source of supply, and so melting out *in situ*. In the valleys of the Gairney Water and the Gelly Burn the ice was probably thicker and would remain longer. Outwash from it may account for the smooth surface of much of the plain west of Loch Leven, which is otherwise out of keeping with the melting out *in situ* of extensive ice-masses. This explanation is supported by the gentle slope of the sand and gravel surface from a steep bank, about 20 feet high, overlooking the flat floor of the eastern end of the Gelly valley to a lower and rather less steep bank near Kinross (Fig. 2). It is probable that at least the higher of these two banks is an ice-contact slope, marking the position of ice in the Gelly valley, and that outwash material was spread over the area between it and a detached mass of ice lying over the site of

Kinross, and possibly extending into the area now occupied by Loch Leven. The Drungie Knowes, already referred to, occupy a central position in the Gelly valley, and as Charlesworth suggested, may well mark the position of a sub-glacial stream.

Loch Leven, with a surface level of 350 feet O.D., is in places 80 feet deep, and while it may in part mark the site of a large detached mass of ice, the hollow it occupies must to some extent be an erosional feature, although it is not clear how it originated. The lake was originally more extensive than at present, and as mapped by the Geological Survey, a former shoreline at *c.* 370 feet O.D. may be traced at a varying distance from the present shore (Figs. 2 and 3). As is suggested in Figure 3 the extended Loch Leven must have been preceded by a small ice-dammed lake occupying the triangular area crossed by the River Leven between the present loch and a narrow defile at Auchmuir. This defile has been cut across a col whose initial height can have been little below 400 feet O.D., and must therefore have been initiated by outflow from a lake at a higher level than even the extended Loch Leven.

The stagnation of ice in the plain was accompanied, as has been demonstrated, by a retreat downslope of the margin against the surrounding hill slopes. A projection westwards of the gradient of the Hattonburn channel suggests that when this channel was in use ice in the Warroch West valley probably reached a level of 900 feet O.D. Meltwater drainage was confined to short channels, of which the one-sided channel at 800 feet O.D. south of Arlick Hill is an example. Possibly initiated at this stage was the channel by which the Lee Burn joins the Warroch West Burn (Figs. 2 and 3). The lower section of this channel, which bends sharply towards the ice-edge, may have developed sub-glacially, but later functioned as a normal channel carrying water from ice in the Cloon valley.

Further west, Glen Queich was developed as a meltwater channel by drainage from the western Ochils. The initial height of the col through which it is cut was approximately 1,000 feet O.D., and the channel probably came into existence at about the same time as the Lee-Warroch channel described above. It is now a narrow trench 300 feet deep, but in the early stages of its development the present outlet was apparently blocked by ice, and meltwater turned eastward into a branch channel about 100 feet deep, whose intake now hangs 150 feet above the floor of Glen Queich. The lower part of this branch channel, known as Keerie Glen, deepens rapidly beyond a rock step, and was clearly rejuvenated while in use as a meltwater channel. There is no indication of the route followed by meltwaters on leaving the Keerie Glen channel prior to this rejuvenation, and they may have drained across or under the ice itself. The rejuvenation probably reflects the shrinkage of the ice away from the valley to which the Keerie Glen drains, which is shown, by a slight discordance of their junction, to have continued in use after the Keerie Glen was abandoned. Rather broad at its upper end, this channel narrows as it swings round Downeri (Fig. 2), and continues along a rectilinear course until it joins the North Queich valley on the south side of Drumgarland. In its early stages of development, however, it probably terminated at the eastern end

of Downeri. An area of sands and gravels between this hill and Drumgarland appears to mark the site of a small lake, dammed by the ice-edge on its southern side. The sand and gravel deposits of the former lake now rise as a smooth terrace above the later extensions of the meltwater channels on either side of it—a headward extension of the Drumgarland channel as the col across which it is cut was lowered, and a downstream extension of the Downeri channel as the ice-edge shrank back and the lake was drained.

The Drumgarland channel, which has a maximum depth of 100 feet and is nearly a mile-and-a-half long, had two successive outlets. One, as has been noted, led to a gravel terrace apparently formed as meltwaters flowed eastward along the ice-edge to the Milnathort moraine. A slight retreat of this edge allowed the meltwaters to turn sharply southwards, cutting a short channel through the terrace and descending to the 500-foot contour. They then appeared to have followed almost the same easterly course as before, but now flowed at the foot of the terrace, in doing so probably trimming back the ice-contact slope of the terrace edge. This route is marked at intervals by mounds of gravel, some little distance away from the terrace, with markedly steeper slopes facing the terrace (Fig. 2). It is possible that this route was still followed for a time when the second Drumgarland outlet came into use a short distance further west. This also descends to 500 feet O.D. It was in turn abandoned as continued shrinkage of the ice permitted the extension of the Downeri channel and the development of the channel on the south side of Drumgarland, now occupied by the North Queich. After the establishment of this route ice may well have disappeared from that part of the plain over which the North Queich flows.

The continued shrinkage of the glacier which allowed the development of successive meltwater routes near Drumgarland is also traceable further west, where Keerie Glen was abandoned in favour of the present outlet of Glen Queich. Meltwaters using Glen Queich for a time continued to escape by the Downeri channel, until a further shrinkage allowed them to take up the course now followed by the South Queich. The sands and gravels which had been spread over the floor of the broad upper end of the Downeri channel (Fig. 2) were now dissected, giving steep bluffs 15-20 feet high overlooking a lower terrace, into which the meltwater stream once more incised itself to produce the steep-sided, flat-floored trench now occupied by the South Queich This last incision is apparently the result of adjustment to the lower level of the plain further east after the disappearance of the ice. The surface over which the South Queich flows after reaching the plain about half-a-mile below Carnbo (Fig. 2) is one of almost horizontally bedded sands and gravels, probably spread out by the meltwaters which continued to use Glen Queich, and by those which joined the South Queich route at Carnbo from the Hood's Hill lake (Fig. 2). In contrast to the other channels so far described, Glen Queich must have been utilised by meltwaters for some time after ice had disappeared from its immediate neighbourhood, by virtue of its function as the sole outlet for water from the western Ochils while ice lay across the mouth of Glen Devon.

As is suggested in Figure 4, the ablation which resulted in the

emergence of Hood's Hill and the stagnation of ice covering much of the plain of Kinross was probably accompanied by a similar thinning of that over the present course of the Devon west of Hood's Hill. For a time an ice-edge may have lain along the line suggested for the final stage shown in Figure 3, running south-eastwards from a point near the entrance to Glen Devon to Hood's Hill. The site of a small lake, dammed by this ice-front, is marked by the flat and peaty area in the angle between Hood's Hill and the Ochils (Fig. 2); this lake drained eastwards by a shallow spillway to augment Glen Queich water at Carnbo, and probably received some water by way of a lateral terrace from Glen Devon. At this stage stagnant ice may still have remained in the eastern parts of the plain, particularly in the Gairney and Gelly valleys. South of Crook of Devon a long boulder-clay ridge containing some boulders of moderate size appears to mark the position of the ice-edge in this area, and may be one of the "marginal accumulations" mentioned by Charlesworth. The irregular surface of sands and gravels within the area roughly delimited by these two positions of the ice-edge strongly suggests that here again the ice stagnated, and it is probable that the eventual complete disappearance of ice over the areas east and west of Hood's Hill took place at much the same time.

The Hood's Hill lake was drained as the ice continued to shrink, and a shallow channel of spillway-form running south-eastwards from Fossoway to Drum (Fig. 3) possibly marks a later position of the ice-edge, and served to carry water from Glen Devon. This channel

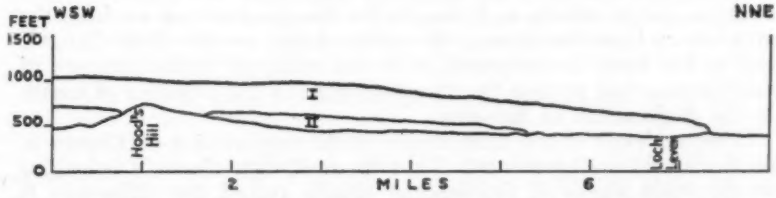

Fig. 4. Section showing probable thickness of ice when (1) the Hattonburn channel functioned; (2) the lateral terrace from Drumgarland channel to the Milnathort moraine was in use.

becomes lost in the irregular surface of sands and gravels, between Drum and Crook of Devon, which may indicate that drainage here became sub-glacial. The actual route followed may be marked by ridges of esker-form at Drum which run south-eastwards into the Gairney valley. Some of the evidence of events in the period just before the complete disappearance of the ice from this area has probably been destroyed by the River Devon in developing its flood plain above Crook of Devon.

The remarkably sharp turn made by the river at the Crook has given rise to much discussion, which has been summarised elsewhere [7]. Recent re-examination of the area by Professor D. L. Linton and the writer suggests that the turn reflects irregularities of the surface left by the melting ice. The lowest point in the Crook of Devon area, which would naturally guide the river in finding a course across a recently ice-covered surface, appears to have been a shallow col on the north

side of the ridge on which Crook of Devon village is built. It was probably only a few feet lower than the Devon-Gairney Water divide, but there is no sign that the Devon ever crossed this slight barrier to enter the Gairney valley. Instead, it turned across the col to enter an almost completely enclosed hollow between the Crook and Rumbling Bridge. A small lake must have been formed in this hollow, as Geikie suggested [8], until the water was able to find an outlet across the ridge closing it on its western side, so initiating the well-known gorge at Rumbling Bridge. As this outlet was lowered, and the lake drained, a narrow defile some 15-20 feet deep was cut across the Crook of Devon col. The sands and gravels at this point are only a few feet thick, so that the defile is in part cut in rock. This has had the effect of retarding the rejuvenation of the river upstream, and has allowed the development of the flood plain already mentioned at the expense of the glacial deposits.

With the establishment of the Devon on its present course the drainage of Kinross was on the whole established in its present pattern. Certain changes occurred, chiefly as a result of the formation of corrom divides where certain of the hill streams reached the broad, gently sloping floors of the former meltwater channels. These have in some cases reversed the direction of post-glacial drainage through the channels. Gorges of adjustment have been formed on some streams which were left hanging above a rapidly deepened meltwater channel, or whose course was changed by a corrom divide. The direction of the major streams, however, appears to have been unaffected by such changes, and to remain as it was on the disappearance of ice from the area. Away from the streams, the surface forms are also little changed, and as has been demonstrated, it is this relatively limited amount of modification that permits the reconstructions of the sequence of events in the deglaciation of the area.

The evidence of the main stages of the deglaciation of Kinross is, on the whole, well-preserved. Thus the meltwater channels belonging to the early stages of deglaciation clearly record the difference in levels of the two major ice-masses which influenced the area. Both these and the later channels of the marginal type more usually described permit the gradual decay of the Kinross branch of the Forth glacier to be traced with reasonable confidence. In Kinross the eventual stagnation of this ice with its detachment from the main glacier to the west appears to result from a purely local accident of relief, the low hills in the west of the plain being just sufficiently high to emerge from the ice-surface when large areas to the east were still ice-covered. However, it should be noted that Sissons has described a similar stagnation of the southern margin of the Forth glacier in East Lothian [9], and Synge has also recorded stagnation at the margin of the Strathmore ice [10]. This suggests that the stagnation in Kinross was due to more than local influences, and reflected the general climatic conditions bringing to an end the last major glaciation to affect the Scottish Lowlands.

The author wishes to express her thanks to Professor D. L. Linton for his helpful suggestions and comments on the Crook of Devon area, both in the field and in the preparation of this account, and to the University of Glasgow for grants towards fieldwork in Kinross in 1954 and 1955.

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THE NEW TIMES ATLAS COMPLETED: A REVIEW

C. KOEMAN

Now that the last volume (II) of the five is soon to appear and its plates 25-48 are available, the time has come to comment on the complete issue of *The Times Atlas*. Such comments, provided by a Dutchman, in whose country no publication of 'hand-atlases' exists and where those wishing to purchase those big atlases have to rely on foreign products, will not be influenced by traditional or patriotic sentiments. Although there exists a Dutch private cartographic industry, which has developed very satisfactorily during the last decade, the limited area of the language makes the production of big 'hand-atlases' economically impossible. Nevertheless there exists a serious interest in atlas production, stimulated presumably by reminiscences of the times when Dutch editors provided the whole map supply of the learned world.

As there is a strong element of tradition in cartography in general and in atlas cartography in particular, it might be well to start this review by answering the question whether or not the new edition of *The Times Atlas* demonstrates such a traditional concept of atlas-making. It definitely does. The new *Times Atlas* is based on the purest principles of traditional atlas-making, originating in the late seventeenth-century French atlases. These concepts have as a starting point: exclusively geographical maps, of a uniform style and, as far as possible, on a uniform scale; no text, no detailed thematic maps and no photographs. How difficult it is to defend these principles against the increasing demands for 'hand-atlases' in a modern style can be shown by the current trend in Germany, where even the most voluminous atlases consist of a mixture of geographical and a multitude of thematic maps, text and photographs, and where the great tradition of Stieler, Andree and Debes has not until now been continued.

One should not misinterpret my appreciation of the classical style, as demonstrated by *The Times Atlas*. I am fully aware of the modern concept of geography, which asks for thematic maps, showing the elements of human geography, and I am also convinced of the necessity of disseminating this knowledge of geography by means of visual aids such as photographs and diagrams. But those mixtures of the classical atlas and the textbook form a different category and I am extremely grateful that the great schools of cartography in Edinburgh, Moscow, Milan and Novara have shown themselves to be the guardians of the classical style of atlas-cartography.

Some remarks on the cartographical aspects of the maps in *The Times Atlas*, as compared with the styles at present in use, should now be made. Dominant are the colours of the layering system for the representation of heights. I am not convinced of the necessity to cling to this style, in order to safeguard an element of tradition. Modern development in cartography has proved how the representation of relief by means of shadowing (Austria, Germany, Switzerland) can be very successful, even on small-scale maps. *The Times Atlas* has already partially switched

over to this idea in plates 1, 8, 9 *et alia* and in the really magnificent map of Asia (plate 25). There is of course a loss in perception of relative heights, but an enormous gain in the representation of morphology which is very poor indeed in *The Times Atlas*. In this connection it is regrettable that the inset map of Mt Everest (30) is very disappointing, due to its poor suggestion of relief. In this map the editor has failed to use the opportunity to display, in more than one respect, one of the most spectacular maps of the whole atlas.

It must be pointed out that the layer with the grey cross-ruling screen is alternatively used for heights over 2,000, 3,000 or 4,000 metres. Certainly it is impossible to adopt one standard scale for the *brown* hypsometric tints on all the sheets, but, in view of the consistent change from green to yellow-brown at 200 metres, we might expect to see the same consistency at the border between brown and grey. The introduction, however, of this nice grey is very successful. Contrary to most other atlases that have adopted hypsometric heights, the maps of *The Times Atlas* are very bright. Now it has become a pleasure to look at the colours of a map of Central Asia, which is not always true for other atlas maps.

The same pleasure is derived from a careful inspecion of the lettering, and the lines. Much of the lettering has been done freehand — and in a magnificent style. This style, however, is not the same for all the sheets, which is inevitable, problably, when no stick-up lettering is used. When comparing the most beautiful stick-up lettering type known to me (that of the Swiss Federal Topographic Institute) with the hand lettering, *e.g.* used on that beautiful plate of Asia (25), it must be admitted that this hand-style is unsurpassed. When looking, however, very carefully at the quality of the line-work, at the constant line-width and at the sharpness of lettering and lines, one gets the impression that these qualities could be improved by application of the scribing technique.

Closely connected with the cartographic aspects are the typographic qualities of *The Times Atlas*. The monumental size, made easy to handle by the division into five volumes, the beautiful glossy paper, that retains its purity, even after intense use, the spacious lay-out, all these properties make *The Times Atlas* the most desirable of all the atlases known to the reviewer.

In an atlas review some general remarks should be made on the geographical aspects of the maps. This review, however, has to be mainly *cartographical*, as the reviewer is not a professional geographer. One of the most striking features is the large scale of many non-European maps. In this respect, the Atlas fully answers the trend in modern geo-political thinking.

One presumes it is not merely incidental that the last part deals with South-West Asia and Russia. Since 1955 the excellent Soviet Russian *Atlas Mira* and its derivates have provided the world with very complete information on the geography of the U.S.S.R., The last volume (Vol. II) of the *Times Atlas* has probably used this information as one of its sources and has published the very interesting maps on the scales 1 : 5 million and 1 : 25 million. When comparing the north part of plate 23 (China-West and Tibet), published in 1958, with plate 43 (U.S.S.R., Kazakhstan : Central Asia), published in 1959, we find many important modifications, such as spot heights, place names, roads, boundaries, due to the use of recent Soviet Russian cartographical material.

For a detailed study of the geography of the U.S.S.R. however the maps in Vol. II are not adequate. Comparing the plates of the *Atlas S.S.S.R., Glavnoe upravlenye geodezyy y kartografyy M.V.D.*, Moskwa 1955, on the scales 1 : 1.5 to 1 : 4 million, with those of *The Times Atlas* on the scale 1 : 5 million, it can be realised how radically the originals have been generalised.

In Vol. III some decisions have been taken concerning scale, which have not turned out too successfully. Iceland should be very happy with its scale 1 : 1 million but Denmark, with its dense population, deserves more than its 1 : 1 million scale. One of the dominant features of the map of the Netherlands (plate 60) is the pattern of the canals and of the many dots representing villages. An effort has been made to generalise these patterns, but not very successfully. Here, and on many other plates, too many places are shown. In particular there does not seem to be any reason for the inclusion of so many small villages in Belgium, France etc.

There is some risk in asking a foreigner for a review. He will no doubt display that most primitive exponent of cartographical interest : to look for his home-town and adjacent places. This reviewer was very happy to see the village of his birth in North-Holland (Vol. III, plate 60) but was disappointed to notice so many mis-interpretations of place names in the Netherlands. Some of the names do not

exist at all. Some of them rely on names of churches, roads or canals. Without listing them here, it must be stated that the interpretation of the source material for plate 60 has been very unfortunate. To eliminate even that small risk, that an accent should be laid on minor erroneous *geographic* details of such an outstanding cartographic work, the editors would do well to have some of their maps checked in the countries portrayed.

Summarising the most striking aspects of this new *Times Atlas* stress should be laid on the outstanding merits of Bartholomews in issuing a work in such a style and of such a *conception*. By doing this they have contributed very greatly to the international promotion of the science of cartography. And they have created a monument to the skill and virtuosity of those many cartographers who made the *Times Atlas* with their hands and brains.

The Times Atlas of the World — Mid-Century Edition:
Edited by John Bartholomew, M.C., LL.D.
Vol. I *World, Australasia & East Asia* (1958)
24 double plates, 1 single plate, Introductory text pp. XXVII, Index-Gazetteer pp. 34.
Vol. II *South-West Asia & Russia* (1960)
24 double plates, Introductory text pp. XII, Index-Gazetteer pp. 51.
Vol. III *Northern Europe* (1955)
24 double plates, Introductory text pp. XII, Index-Gazetteer pp. 57.
Vol. IV *Southern Europe & Africa* (1956)
24 double plates, Introductory text pp. XII, Index-Gazetteer pp. 50.
Vol. V *The Americas* (1957)
24 double plates, 1 single plate, Introductory text pp. XII, Index-Gazetteer pp. 57.
Uniform bound size $19^1/_2 \times 12^3/_8$, 120 double map plates (24 × 19), 2 single map plates (12 × 19). Index-Gazetteer of 198,800 names. Maps prepared and printed by John Bartholomew & Son Ltd., Edinburgh. London: The Times Publishing Co., Ltd., £5-5s. per volume.

REVIEWS OF BOOKS

EUROPE

Park: A Geographical Study of a Lewis Crofting District. By Dr J. B. Caird and members of the Geographical Field Group. 10 × 8. Pp. iv. + 40. 10 figures. 20 tables. Produced jointly by Department of Geography, The University of Glasgow and the Geographical Field Group, 1959, 6s.6d.

Since 1955, staff and students of the Geography Department, Glasgow University, have been engaged in a survey of crofting districts. The aim is to record and analyse material relevant to these districts and provide a clear and impartial factual statement of the present position. The Park Survey was undertaken at the request of a local association anxiously seeking help towards improving conditions in the twelve townships with a total population of 900. Dr J. B. Caird of Glasgow University, assisted by Miss Catherine Smith, led eleven members of the Geographical Field Group who, in the course of three weeks of their summer holiday, gathered an amazing amount of detailed information which is now presented in a valuable and readable report edited by Dr Caird who contributes the general chapters. Word pictures of townships have been prepared by individual members of the party and there are illuminating maps and diagrams and a number of useful statistical tables.

One of the most noteworthy features of the series of surveys is that, while previously a certain amount of data was available for counties and sometimes for parishes, the aim now is to gain a true picture of the townships which are the basis of crofting. Whether the reader has already much knowledge of crofting conditions and problems or is seeking an elementary picture of the crofting pattern, the study of this paper will be of value to him. Park is one of the most difficult crofting areas but its problems are common in varying degrees to many townships in the seven crofting counties — the decline of the fishing industry, isolation, small area

of cultivable land, poverty of soil, adverse climatic conditions, lack of industrial and other ancillary occupations, and a rapidly declining and ageing population.

The environmental conditions are fully described and the moulding of the present crofting pattern traced from prehistoric times through evictions, the introduction of large-scale farming, and resettlement. Attention is drawn to the predominance of lazy-bed cultivation, the lack of winter-keep for cattle and a cattle/sheep ratio much too low at 1 : 25 for proper management of grazings; the standard of sheep husbandry is low, with small lambing percentages and poor prices mainly attributable to lack of good grazing and to overgrazing. Park extends to some 24,000 acres of which 22,000 are poor grazings with much rock and peat; only some 500 are designated arable. There are fully 200 agricultural units very few of which by themselves support a family.

The Report discusses in detail the ancillary occupations, seasonal and regular, at home and away, and points out that Park makes quite a considerable contribution to the National economy in domestic servants, nurses, merchant seamen, etc. But there is a continuous draw away of the younger age groups, the destination of the emigrants being significant: Stornoway, the one place in the islands where enployment is available, heads the list with one third, which may indicate that if employment were available in Park, the migration rate would be drastically cut. Tentative suggestions regarding the provision of employment and the revival of fishing are made. In so far as agriculture is concerned the aim might be to create crofting and non-crofting groups so that agricultural units would be reduced in number by half at least. Amalgamation will come in any case as a result of uncontrolled rundown of the community; should there be planned amalgamation? Improvements in the standards of husbandry are taking place and should be encouraged not only on the arable land but by reseeding on outrun and common grazing. There should be investigation into the problem of minimum size of agricultural units to secure viability, and into the optimum size and structure of the population. The material contained in this Report provides food for thought concerning the future of Park. Those engaged in this and the whole series of surveys are making a valuable contribution towards the solution of the problems of the Highlands and Islands. M.A.M.D.

Scotland Past and Present. By J. M. Reid. 7 × 4½. Pp. 200. 1 Map. London: Oxford University Press, 1959, 7s.6d.

Scotland Past and Present in the Home University Library is an admirable survey of Scottish Life and Institutions. It is a difficult task to unravel the many-sided facets of "a nation which for 250 years has kept its individuality without the political framework of a state to support it", but Mr Reid has succeeded in producing a readable book, based on and supported by well-chosen facts, and both sides of tendentious topics are put to the reader. *Scotland Past and Present* is a useful book for Scots. and an ideal introduction for non-Scots J.B.C.

BIOGEOGRAPHY

Photographic Documentation of Vegetational Changes in Africa over a Third of a Century. By H. L. Shantz and B. L. Turner. 11 × 8½. Pp.158. 150 plates. 1 map. 9 graphs. University of Arizona, College of Agriculture, Report 169, August 1958.

In 1956-57 Dr Shantz returned to Africa to re-photograph, at approximately the same time of the year, as many as practical of the sites that he had recorded nearly forty years before. His aim was to document the vegetational changes which had occurred during a third of a century, over an area which extended from the Union north-eastwards to Kenya and Uganda.

This selection of duplicate photographs, briefly annotated and arranged in accordance with the broad vegetation belts recognised and mapped by Shantz and Marbut in 1923, has been published posthumously. The idea was certainly an excellent one but, unfortunately, the result is very disappointing. The quality of the photographs and of their reproduction is rarely good enough to show clearly those changes that have taken place; while in the majority of the plates little or no

change is, in fact, recorded. Except in the case of Savana vegetation where short grass has frequently replaced long grass, the most frequent and obvious change is an increased density of vegetation cover — due either to rapid secondary growth on a formerly cleared or cultivated area, or to a marked increase in succulent and thorny scrub as the result of excessive fire, even in areas of relatively high rainfall. But the number of sites in relation to the area traversed is very small and it is difficult to assess how far these photos are representative of the degree and nature of change that has taken place within the major vegetation belts as a whole. In proportion to the time and energy expended, the conclusions are slight and the result is an interesting historical document of limited application. J.T.

Zoogeography, A Symposium. Edited by C. L. Hubbs. 9 × 6. Pp. X + 509. 115 figures, 12 tables. Washington, D.C.: American Association for the Advancement of Science, Publication No. 15, 1958.

The modern expansion of scientific knowledge has made periodic summaries and discussions of most branches a necessity. One of the very useful means of achieving this end is by holding a symposium, and the present volume is a good example of what may be done by this means. It consists of a collection of papers from two symposia held to discuss the question of the Zoogeography of North America, and more particularly of the western part.

The first symposium deals with "The Origins and Affinities of the Land and Freshwater Fauna of Western North America". The report contains fourteen articles the first four being devoted to introductory matters such as Geology, Climatology, Palaeontology and Physiology. The remainders are concerned with the vertebrates and insects. The second part of the report has but three sections, "Pleistocene Ecology", "The Palaeartic element in the Avifauna etc." and "The Distributional pattern of the Vertebrates of the area". The Editor appends a summary of the whole report.

In such a volume as this there is bound to be a wide diversity in the topics discussed and in the method of approach. It has been written by well-known American scientists, mainly drawn from the Universities, and is a series of individual contributions. Some of the accounts are summaries of some phase, others are very full studies based on the author's research and long association with his subject.

Of the seventeen sections, only two are abstracts, the others are fuller contributions, and all but one include a list of the more important relevant papers. Most, also, have useful diagrams and maps in black and white.

This volume provides an interesting summary of the Zoogeography of North America and should be a useful guide for those who wish to know more about the subject, since it not only gives a mass of interesting information, but summarises a type of literature not readily accessible to the average reader in this country. A.C.S.

CARTOGRAPHY

Ordnance Survey One-Inch Tourist Series: Lorn and Lochaber 32 × 40 Ordnance Survey, Chessington, 1959. Paper flat 4s., folded 6s., mounted and folded 8s.6d.

Four sheets — *Peak District* (1957), *North York Moors* (1958), *Lake District* (1958), *Lorn and Lochaber* (1959) — have so far been published by the Ordnance Survey in the new post-war *One-Inch Tourist Series*. The first three cover National Park areas in England and the last a popular area of the Scottish Highlands. All are based on the *One-Inch Seventh Series* with the addition to the contours of varying combinations of layer-tints and hillshading as a means of showing relief. The object is to enable an inexperienced map-reader to obtain an immediate visual impression of the hill and valley slopes and in this they all succeed to a greater or lesser degree. The first two named use seven, carefully graded layer-tints with a rather apologetic overlay of hillshading, and the overall balance of the delicate tints is pleasing if a bit flat. One might be excused, however, for wondering why such a wide line-screen was used for the green layer-tint on these two sheets.

The two later sheets *(Lake District* and *Lorn and Lochaber)* make very limited

use of layer-colouring with only a pale-green tint for the lower ground (below 500 feet and 100 feet respectively) above which a more vivid hill-shading style has been used. Two colours, apricot and plum, of varying tone are used to bring out the changes of slope and exposure in relation to the assumed north-west light and south-east shadow respectively. There is however no doubt that the result is much more successful in the case of the *Lorn and Lochaber* sheet where greater light and shadow contrasts give increased virility compared with the *Lake District*.

The advent of a tourist map with a new look is an important occasion, and the Ordnance Survey are to be congratulated on producing the most handsome coloured map they have published to date.

It is appropriate and commendable that the maximum artistic effort should be devoted to the interpretation of relief in areas of great scenic beauty. *Lorn and Lochaber* can well be described as a 'cartogenic' area, if a photographic derivative can be coined, for here is a happy blend of glen and ben with forest and loch where hillshading has been used to great advantage. While the tone contrasts and emphasis given to the relief have achieved a happy balance in appearance, the treatment is inadequate in detail and misleading when it comes to precipitous and rocky features. If comparable progress could be achieved with the rock-drawing as has been accomplished with the hillshading, the result would surely be worthwhile.

The green forest tint is not over-obtrusive, but the tree symbols, normally grey on the *Seventh Series*, are black here, and by their boldness detract from the otherwise restrained effect.

It is unfortunate that the strength of the blue tint for water has been reduced as compared with the *Seventh Series*, as witnessed by the anaemic result for uncontoured lochs and reservoirs.

As the upper edge of the light-green layer-tint coincides with the 100-foot raised beach, it ideally delimits the associated coastal platform and river terraces.

The Ordnance Survey can afford to feel pleased with the progress made in these tourist sheets so long as they are not content to rest there. J.C.B.

Lexique Anglais-Français. By R. Thuillier and S. de Brommer; in two parts (first part consisting of 2 volumes); 8 × 10½. Pp. XIV + 573. Paris: Institut Géographique National, Service de la Documentation Technique, 1958, 2,800 Frs.

When the French Ordnance Survey (Institut Géographique National) was demobilised, it underwent a complete rejuvenation. The new lease of life is to be seen in all departments; as for example in the new magnificent building at Saint Mandé, in the rebuilt section on Rue de Grenelle in Paris; in the astonishing programme of surveying and mapping, and last, but not least, in the list of useful and intelligent publications. We may mention the Relief Form Atlas, published in 1956; 2 volumes of map projections entitled *Les Systèmes de Projection* in 1957; and, in 1958, *Lexique Anglais-Français* — the subject of this review.

This publication provides the French cartographer with a tool which opens up easy access to the cartographic literature of Great Britain and America. Part I contains two volumes. Volume I, after an introductory note, gives the vocabulary proper, covering the whole field of mapping from surveying to the final drafting of the maps (278 pages). Volume II has four sections printed on alternate colours of paper. Section I (pages 280-387) gives English and American abbreviations. Section II (pages 1-165) lists the mathematical notations and the units used in physics: German is also used (all three languages) in this section. Section III (pages 1-20) gives the Anglo-Saxon scale expressions, sizes of paper sheets and photographic formats in inches and centimetres, conversion tables for inches into centimetres, feet into metres and statute miles into kilometres; the conversion of Fahrenheit into Centigrade, and finally, the comparison of different scales of photographic sensitivity. Section IV deals further with map projections.

Part II has a vocabulary of 102 pages of English and American expressions used in map reproduction, plus 30 pages repeating section 3 from the second volume, Part I. It would be a boon to British and American cartographers if a similar key to French cartographic literature were to be made available. J.J.K.

The World's Lighthouses before 1820. By D. Alan Stevenson. 9 × 11½. Pp. XXIV + 310. 199 illustrations, 7 maps. London: Oxford University Press, 1959, 63s.

The Society will wish to congratulate one of its senior Trustees on this magnificent book. Mr Stevenson is a member of a long-established Scottish firm whose name has been in the top flight of lighthouse engineers for generations. He has drawn on his own long practical experience of lighthouses not only in Scotland but overseas, on family records and on a wide range of published and unpublished sources. The result is a definitive study which will be a standard work for a long time. This volume, the first of two, treats of the oldest seamarks, traces the introduction of more modern illuminants and of reflectors and lenses, and culminates with one of the major achievements of his own family, the Bell Rock tower, which is noteworthy in that it is the last major lighthouse to be built before the introduction of steam power made such projects considerably easier. Other famous and historic lights in North America and Europe are dealt with and altogether a noteworthy contribution is made not only to the study of navigational aids, but to an understanding of the development of navigation in commerce and exploration. R.M.

ROYAL SCOTTISH GEOGRAPHICAL SOCIETY

PROCEEDINGS

MEETINGS OF COUNCIL were held on 11th December, 1959 and 12th February, 1960.

OBITUARY: Dr W. Clarke Souter, Vice-President 1951-59.

LECTURE SESSION 1959-60

The following lectures were delivered: —

EDINBURGH: *Usher Hall* - Major W. T. Blake on "African Journey", 10th December. Ernest Eytle on "The West Indian Scene", 14th January. Stanley Jeeves on "The Oxford and Cambridge Expedition to South America, 1957-58", 11th February. J. Andersen - Rosendal on "Spotlight on China", 10th March. *Central Hall* - John Marshall on "Bremen to Brenner", 2nd December. Richard H. Osborne, B.Sc. (Econ.), Ph.D., on "The Changing Face of Eastern Europe", 16th December. Donald E. Baird on "North Rona Venture", 20th January. Robert Grieve, A.M.C.E., M.T.P.I., on "A Winter Ski Tour in Norway", 3rd February. Ian A. G. Kinniburgh, M.A., on "Some Harbours of The Forth and Clyde", 17th February. J. P. Cole, M.A., "The Geography of World Problems", 26th February. Mrs. Myrtle Simpson, M.S.R., on "The Edinburgh Andean Expedition, 1958", 2nd March. Adam G. Brown on "Holiday in Europe", 16th March.

GLASGOW: *St Andrew's (Grand) Hall* - Major W. T. Blake on "African Journey", 9th December. Ernest Eytle on "The West Indian Scene", 13th January. Stanley Jeeves on "The Oxford and Cambridge Expedition to South America, 1957-58", 10th February. Dr C. G. M. Slesser on "The Scottish East Greenland Expedition, 1958", 2nd March. *St Andrew's (Berkeley) Hall* - Richard H. Osborne, B.Sc. (Econ.), Ph.D., on "The Changing Face of Eastern Europe", 17th December. Donald E. Baird on "North Rona Venture", 21st January. Donald G. Moir, F.R.S.G.S., on "1959 R.S.G.S. Tour to U.S.A. & Canada", 1st February. Ian A. G. Kinniburgh, M.A., on "Some Harbours of The Forth and Clyde", 18th February. Adam G. Brown on "Holiday in Europe", 17th March. *The Burlington Restaurant* - Lecture Lunch - 26th March.

ABERDEEN: *Y.M.C.A. Hall* - Miss Isobel W. Hutchison, LL.D., F.R.S.G.S., on "Corsica", 7th December. Richard H. Osborne, B.Sc. (Econ), Ph.D., on "The Changing Face of Eastern Europe", 11th January. Stanley Jeeves on "The Oxford and Cambridge Expedition to South America, 1957-58", 8th February. J. Andersen - Rosendal on "Spotlight on China", 7th March.

DUNDEE: *St Paul's Hall* - Miss Isobel W. Hutchison, LL.D., F.R.S.G.S. on "Corsica", 8th December. Richard H. Osborne. B.Sc. (Econ.), Ph.D., on "The Changing Face of Eastern Europe", 12th January. Stanley Jeeves on "The Oxford and Cambridge Expedition to South America, 1957-58", 9th February. J. Andersen - Rosendal on "Spotlight on China", 8th March.

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